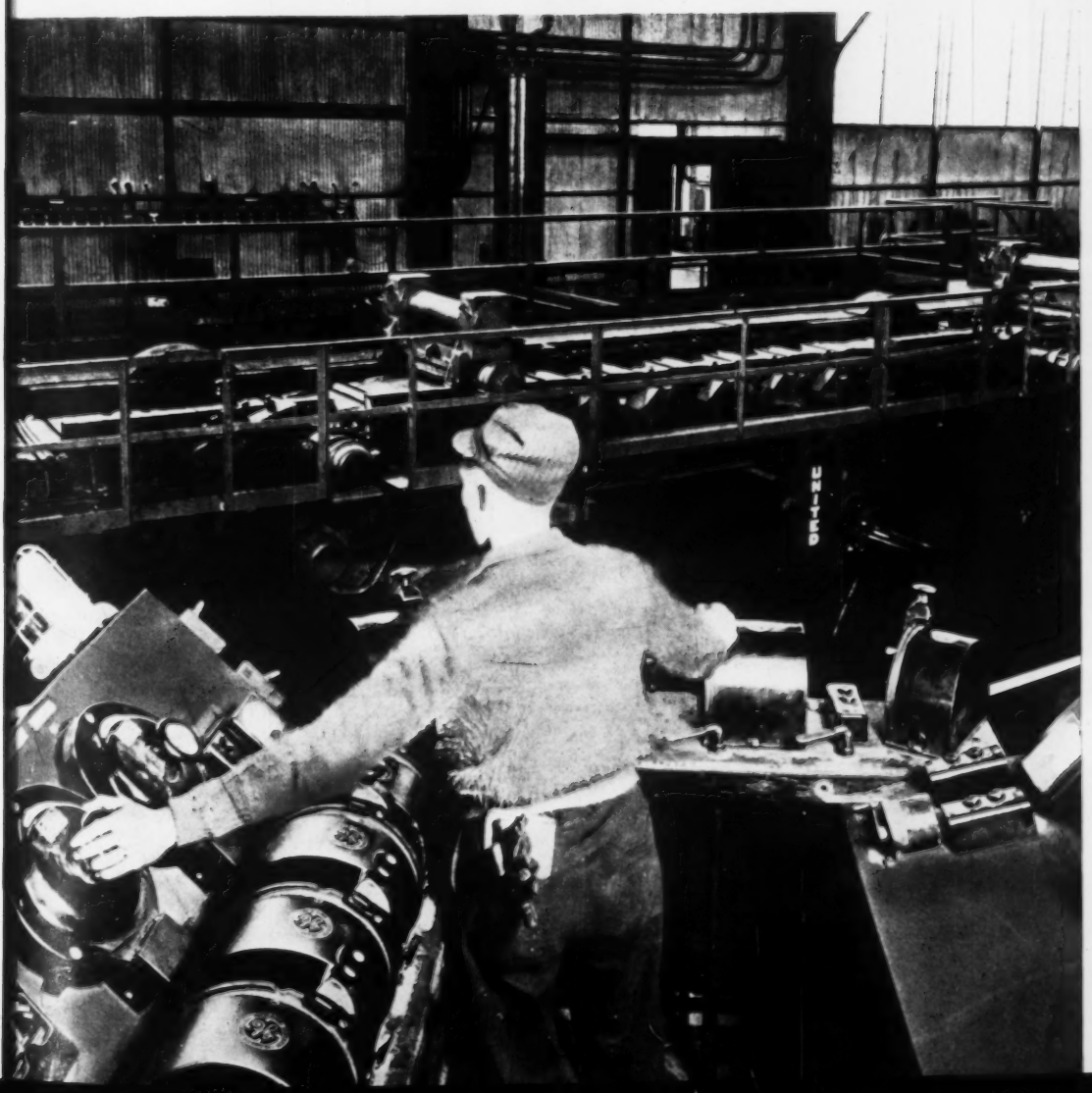
INSTRUMENTS

THE MAGAZINE OF MEASUREMENT and CONTROL



VOLUME 9

AUGUST 1936

NUMBER 8

Locate AND *Stop*

YOUR WASTED POWER . . . WITH

WESTON Junior Portable Test Instruments

The amount of power wasted through gear misalignment at *one* machine may not be serious today . . . although, tomorrow, it can be wasting as much as 5% of the transmitted power . . . and a few days hence a costly breakdown follows. But add to this loss from one gear box similar power losses from other machines . . . and from tight or loose belts, shaft misalignments, over-loaded motors, worn impellers, bearing friction, etc. *The accumulation of these losses becomes a sizable sum.*

All of these losses can be eliminated . . . full utilization of the transmitted power at every point on the production line can be assured . . . with inexpensive WESTON maintenance tools. A quick, periodic check of all electrical units with WESTON Junior portable test instruments instantly signals any potential trouble, and permits correction before serious loss occurs. And in most cases, the detection of one leak saves more than the cost of these instruments.

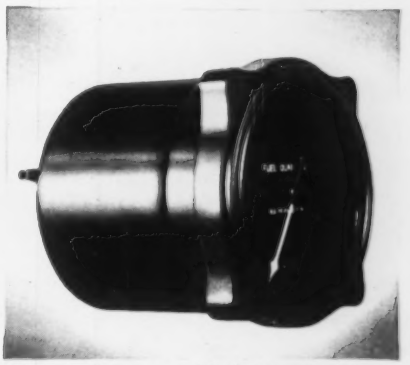
WESTON Junior Instruments are small, compact, rugged and inexpensively priced, yet they have the full dependability which the name WESTON implies. They include DC instruments, AC instruments and single phase Wattmeters. Ask for complete literature . . . WESTON Electrical Instrument Corporation, 591 Frelinghuysen Ave., Newark, N. J.

WESTON

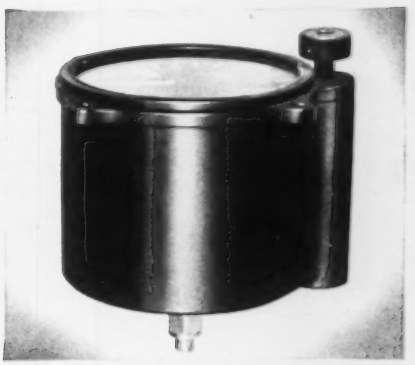
Instruments

Instruments *of Enduring Accuracy* for Army and Navy Service

Bakelite Molded housings and mechanical and electrical parts for Pioneer Army and Navy-type aviation instruments.



Pioneer Navy-type Fuel Quantity Gauge with case of Bakelite Molded.



Pioneer Rotatable Air Speed Indicator with case of Bakelite Molded.

INSTRUMENTS designed for Army and Navy aircraft service must possess enduring accuracy. It is significant that Bakelite materials are employed for many vital parts of these precision instruments.

The above group is typical of hundreds of Bakelite Molded instrument parts, used not only in government service, but in all branches of industry. Included are an instrument case, fuel gauge, air speed indicator and compass front plates, electric plug and lamp bracket.

Characteristics of Bakelite Materials that contribute to the unchanging dependability of instruments are their mechanical strength and toughness, low coefficient of expansion, stable electrical properties, and high resistance to moisture, heat, fumes, oil and distortion.

Technical men are invited to familiarize themselves with the several different types of Bakelite Material now finding wide application in the betterment of instruments. Write for booklets 37M, "Bakelite Molded", 37L, "Bakelite Laminated", and 37V, "Bakelite Varnish".

Army-type compass, with Bakelite Molded parts. Made by Pioneer Instrument Company, Inc., Brooklyn, N. Y.

BAKELITE CORPORATION, 247 PARK AVENUE, NEW YORK, N.Y.
BAKELITE CORPORATION OF CANADA, LIMITED, 163 Dufferin Street, Toronto, Ontario, Canada

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THE MATERIAL OF A THOUSAND USES

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at Carnegie-Illinois Steel Co., McDonald, O.
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INSTRUMENTS The Magazine of MEASUREMENT and CONTROL

M. F. BEHAR
EDITOR

IN THIS ISSUE

Is there such a physical property as "hardness"? No one is better qualified to answer than a physicist who in the last quarter-century has made many notable contributions to this topic. But Professor Williams, too wise to blurt out yes or no, chooses to point out the heretofore unappreciated division of "hardness" measurements into four distinct factors, two of them related to the penetrator and only two being physical properties of the specimen. He hints, however, that there may be "positive" ways of measuring "absolute" hardness. His article, undoubtedly a milestone in the progress of mechanical testing, may likewise mark the long-awaited turning-point from arbitrary to rational methods.

Has *Instruments* an altruistic mission, entirely apart from its existence as a business enterprise? It has several, and one is to promote highway safety by publishing articles on using instruments for improving the various factors involved—psychological (driving-skill, etc.) elements and purely physical elements. From time to time we have secured exclusive disclosures, but it is natural that the SAE should in most cases have first call, and it was before the SAE that Messrs. Bockius and Hunt presented their notable paper on brake drum and lining developments. The original paper ran to 17 pages in the *SAE Journal;* the article which we are privileged to publish covers only the "instrument part"—but this part is most significant.

R. R. Batcher describes this month various cathode-ray tubes for uses other than oscillography.

The "control" part of the electrical measurements and control serial continues, with discussions (due to Perry Borden) of some types for which there is a great future. In last month's instalment the G-E "GDA" regulator was discussed with others under the title of "carbon-pile"—and this drew protests from several G-Engineers: one wrote us that "to call its resistance element a carbon pile is like calling a Lincoln Zephyr a Model T." . . . Sorry!

CONTRIBUTE!

By S. R. WILLIAMS, member of *Instruments'* Editorial Advisory Board, whom we take pleasure in appointing Guest Editor—an appointment which will surprise him as much as the receipt of his flattering letter surprised us.

To the Readers of *Instruments:*

From several "blurbs" which the Editor of *Instruments* has been good enough to publish as emanating from our laboratory, I am surprised to find how wide a circulation *Instruments* enjoys. Letters of comment on the aforesaid articles have come in, not only from North America, but from European countries as well.

This leads to a plea that the large mass of information collected by investigators in private and commercial laboratories and which is lying unused in many instances, should be sent to the Editor of *Instruments* for his consideration as material for publication. Put the material into circulation. Often there are shop practices in measurements and the use of instruments which would be most useful to others. Why not put such information into a note and send it to Major Béhar? When he puts two blue pencils over his ears and a red one in his hand, he can take extremely poor manuscripts (as the writer can testify) and make them into delightfully readable articles, which will go to the four quarters of the earth in the columns of *Instruments.* Not only will you be helping the rest of us but you will be helping *Instruments* keep up and advance its position as a medium of exchange of thought on the important subjects of Methods of Measurements and The Technique of Instrumentation.

Although Editor Béhar has an unusually liberal policy in regard to material for the columns of *Instruments,* naturally, someone must make a final decision regarding what shall go in, and the Editor must make that decision. Major Béhar may turn down material submitted for publication, but this in no way says it is not good material. Merely does it state that in his judgment it has been covered in some other article or is best served by some other publication. The point is:—keep an uninterrupted flow of articles (long and short) to the editorial desk so that there will be a chance for selection of the best. Yours may be among this material. Do not forget to include good photographs if you happen to have them as they help to make clear the methods of measurements.

Amherst, Massachusetts,
July 21, 1936.

Cordially,
S. R. WILLIAMS

INSTRUMENTS' READERS AT WORK

No. 13—CLIFFORD AYLWARD HAHN, Chief Engineer
No. 14—JOHN STEWART GIBSON, Combustion Engineer
No. 15—EDWARD HARRISON CONNOR, Ass't to Chief Eng.
No. 16—JOHN R. WILLIAMS, Instrument Maintenance Man

H. J. HEINZ CO. ("*The 57 Varieties*") *PITTSBURGH*

By M. F. BEHAR

THROUGHOUT the far-flung Heinz empire of 21 factories in North America, thousands of workers use instruments incidentally; hundreds of engineers, dieticians and laboratory technicians work purposefully with instruments; but the company subscriptions to *Instruments* are anonymous, so that when we visited the huge Pittsburgh plant (30 buildings, 3000 employees) we had quite a job selecting "typical" readers: should we assemble on this page a group representing the various "divisions" or the various "product departments" (virtually independent factories) or the various "service departments" (engineering, quality control, etc.)? Should we pick out one reader at random? Or should we take a "team" from one department?

Learning that most copies of *Instruments* were routed through the Engineering Department, we decided upon the last-mentioned idea, and now take pleasure in introducing to you a "vertical section" of this 170-man department—from staff captain to buck private.

Born in New York in 1890, Hahn took his B.S. in C.E. at Brown; and then post-graduate work at Brooklyn Poly and Columbia while employed as designing engineer and instructor. In 1915, while on the technical staff of New York City's Board of Estimate and Apportionment, he became closely associated with Robert Moses, then Director of the Bureau of Municipal Research. This association continued during the war when Moses went to the U. S. Shipping Board, Hahn becoming Production Manager at Hog Island in the building of the famous "Bridge of Ships," and Member of the President's Council. After the war Hahn joined the Chief Engineer's Staff of Stone & Webster and aided in the design and operation of some of the world's biggest power plants. In 1928 he accepted the position of consulting engineer with H. J. Heinz Co. in the Pittsburgh office where the supervision of all technical as well as operating activities is centered. Always instrument-conscious, he initiated the studies resulting in the first process-time controllers in this business. His responsibilities are so many and varied that after spending nearly a whole day with him we had only caught a few glimpses. One glimpse: backstage in the company's auditorium (Pittsburgh's finest), the new $60,000 preset lighting control board which alone deserves a two-page article.

Born in 1903 in LaFargeville, N. Y., Gibson attended Syracuse and Rensselaer Poly, taking his M.E. in 1926. After public-utilities experience he joined the Heinz Co. in 1930 as a draftsman. Now, as combustion engineer, he heads the heat, light and power section of Hahn's department.

Connor, too, is a native of New York State (Syracuse, 1891). At 22 he joined the Heinz Company and was first assigned to time keeping and job-cost work, then to drafting and layout. Now, as Assistant to the Chief Engineer, he lays out processing equipment and supervises maintenance.

A native of Johnstown, Pa., Williams is a fine example of an instrument mechanic who believes in educating himself, buying technical books and magazines out of his own wages and studying them so well that he can calibrate orifices.

One last word: *Before* we met Hahn we were told by Publicity Director Laufman that "The man with the instruments is boss at Heinz."

PRINCIPAL APPLICATIONS OF INSTRUMENTS AT H. J. HEINZ CO.

Power Plants—18 steam flow indicators, integrators, and recorders (mechanical and remote electrical types) including air flow equipment in some cases. 5 Venturi and V-Notch boiler feed indicators and recorders. 6 coal meters to record fuel to pulverizers. 1 coal beam scale traveling larry. 15 Stack temperature indicating and recording pyrometers. 18 temperature recorders on feed-water, cooling and pre-heating applications.

Departmental Distribution—26 electric steam flow recorders and integrators on kitchen and processing applications. 133 recording and indicating wattmeters and numerous a.c. and d.c. indicating instruments. 34 integrating meters on natural and carburetted gas together with pressure recording and control equipment on toasting and baking operations. 115 pressure controllers and temperature recorders on closed cookers. 7 temperature controllers with recorders on toasting operations using natural gas. 62 time-temperature cycle controllers on pulp cooking operations. 11 temperature controllers and recorders on can-making production line solder baths. 8 indicating and recording tachometers.

Glass Manufacture—Temperature instrumentation on lehrs, tanks and revolving pots.

Laboratory and Inspection—30 microscopes, 10 refractometers, 4 semi-precision potentiometers, 2 polariscopes, 10 analytical balances.

HAHN GIBSON CONNOR WILLIAMS

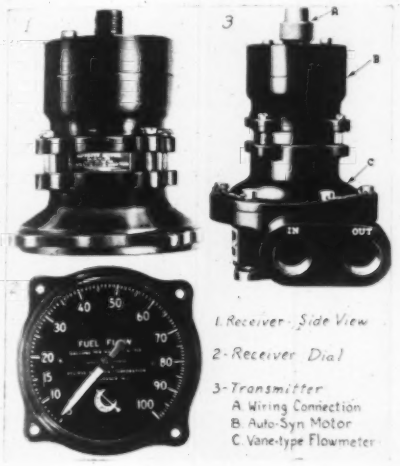
THE MONTH'S NEW INSTRUMENTS

In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions.

When writing to manufacturers directly, please mention this department as your source of information. Or write to Information Section, Instruments Publishing Company.

Remote-reading Flowmeter

Its total weight being <5 lbs. and its range being 0-100 g.p.h. (calibrated for average density and viscosity of aviation gasoline) this new flow-rate telemetering



system was especially designed for aircraft use, but is suitable for other applications where small flows are to be indicated at a distance. In fact, since primary metering element is of vane type, system is applicable where gravimetric rate (rather than volumetric rate) is desired to be continuously indicated. Meter-and-transmitter assembly may be mounted in any position. Telemetering system consists of a pair of "Auto-Syn" position-motors, operated from 32-volt 60-cycle supply provided by tachometer-shaft-driven generator. Pressure drop through primary metering element <0.33 lb./in.^{2} at max. flow rate. Calibration is practicable without disassembly.—*Eclipse Aviation Corp., East Orange, N. J.*

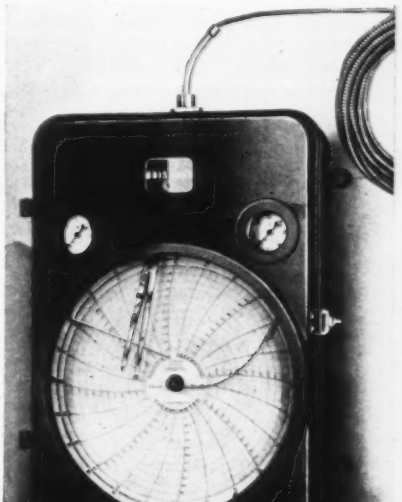
Optical Flats

Three classes of optical flats are announced, all with one surface polished to ¼ wave-length, the other polished for clearly viewing the interference fringes: (1) Fused quartz flats, 2" diam., inap-

preciable temperature coefficient, containing some minute bubbles. (2) Pyrex flats, 4" diam., temperature coefficient negligible for most purposes, some striae characteristic of the material. (3) Plate glass flats, 4" diam., for use where temperature is controlled.—*Mann Instrument Corp., 10 Arrow St., Cambridge, Mass.*

Low-sensitivity Controllers

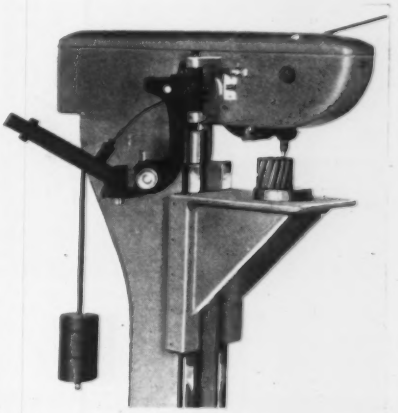
New "Master Free-Vane Controllers" for temperature, time-temperature, flow, liquid level, pressure, time-pressure, and humidity are offered primarily for applications where a greatly reduced sensitivity (wide throttling range) is required and the load conditions fluctuate over a wide range. New model employs "Free-Vane" design of air pilot (see *Instruments*, Jan. 1932, page 9). It is similar in many respects to the "Ampliset Controller (see *Instruments*, June 1936, page 156). The basic Free-Vane system is equipped with a sensitivity adjustment, an automatic reset, and accessory



features which are said to minimize hunting; to prevent departure from control setting; to make it possible to reach a new control setting without overshooting; to permit adjusting the anticipatory effect to fit the process lag and adjusting the resetting mechanism to function in an amount proportional to the rate of change in the process. It is said to be designed to compensate automatically for each of the disturbing elements in industrial processes that, from time to time, have a tendency to upset the true function of the control system. It is said to make it possible to obtain precision control on extremely difficult applications without assistance from the operator.—*The Bristol Co., Waterbury, Conn.*

Hardness Tester

Well-defined square impressions, permitting unusually close measurements, are produced by pyramid-shaped diamond indenter of new Diamo-Brinell hardness testing machine said to be "the



most accurate apparatus for testing all kinds of metals," being applicable to hard and soft metals and alloys. Load is applied by a system of weights and levers. Time of load application, automatically controlled, is always the same. Entire operation is said to be "practically automatic" by virtue of buzzer and light signals which assure correct settings, and of an arrangement whereby stage is lowered and microscope swings exactly over impression and swings back when a catch is disengaged. Diagonal is measured to 0.001 mm.; charts and tables permit expressing result in conventional hardness numerals. Max. test load, 120 kg. Max. clearance, 25"; gap, 6¼".—*Pittsburgh Instrument & Machine Co., 1026 Reedsdale St., Pittsburgh, Pa.*

Portable Volt-wattmeter

In this new combination volt-wattmeter (of maker's "Type AP-9" series of portable instruments) consisting of a voltmeter and a wattmeter fitted into a

standard AP-9 case, either rating may be used by throwing a switch located on top of instrument. Overall accuracy 0.75% of full-scale value. Instrument has magnetic damping and the new Permaloy moving vane; and is shielded from stray magnetic fields. Case is of Textolite.—*General Electric Co., Schenectady, N. Y.*

BAILEY METER
CONTROL SYSTEM

The Mark of

Effective Control

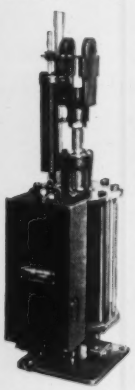
Process Control for sensitive, stable automatic control of temperature, pressure, liquid level, flow and other factors as applied to industrial processes. Responds to changes quickly, without overtravel or hunting. Ask for Bulletin No. 101.

Combustion Control that is simple but *complete* for providing economical operation of boilers of 200 h. p. and larger. Details in Bulletin No. 102.

Recorder-Controller

Boiler Meters for recording combustion conditions and guiding boiler operators. Described in Bulletin No. 44.

Multi-Pointer Gages for indicating factors such as draft, pressure, temperature and speed. These Gages are available with any number of pointers and any scale combination; in either the oil sealed bell or diaphragm construction.



Control Drive

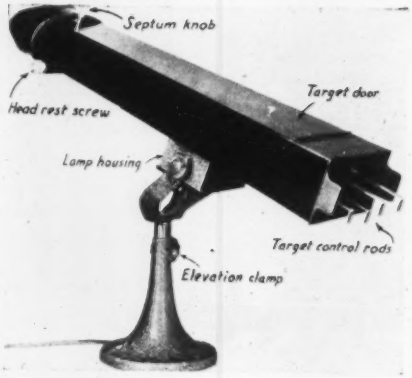
Flow Meters for indicating, recording and integrating the flow of steam, water, sewage, air, gas and other fluids. Bulletins No. 39 and 300.

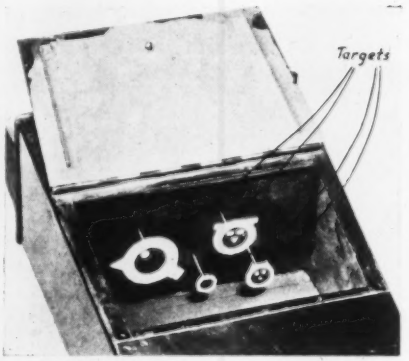
Recorders for pressure, temperature, drafts, liquid level and other factors.

C-3

BAILEY METER COMPANY

1041 Ivanhoe Rd., Cleveland, Ohio



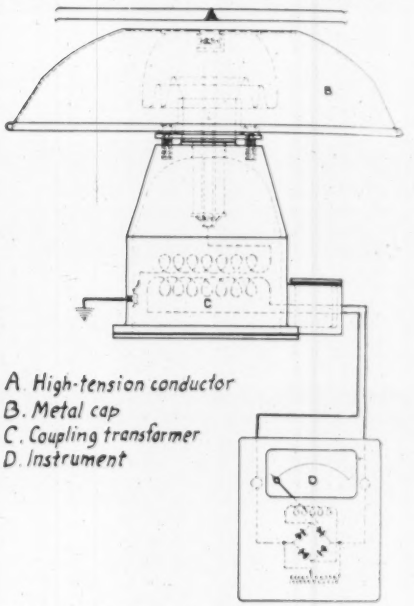


"Depthescope"

Importance of ability to judge distance and depth was brought out by Professor DeSilva in his article on Measuring Driving Skill (*Instruments*, April 1936, pages 101-108). For determining presence or absence of binocular vision and depth perception; for measuring depth perception, and for developing it, the new "Higley Depthescope" employs illuminated and adjustable targets. (1) *Binocular vision test*: The driver is seated before the instrument and an eye shield is adjusted to keep out extraneous light. A septum is then turned in place before one eye. A light is turned on in the instrument and the driver is required to state the depth position of the targets, which have been arranged so that one is as far forward and the other as far backward as possible. Having only monocular vision, the driver cannot perceive depth or he will attempt to describe the apparent position of the targets from the appearance of size. The septum is then turned to a neutral position and the driver if he has depth perception, should be able easily to distinguish the different depths of the targets. (2) *Depth perception measurement*: This is done with two targets. One, a "bird" target, is set 10 mm. from the back of the instrument, or 500 mm. from the eye of the observer. The septum is set at neutral, while the operator moves a "man" target forward about 35 mm. He informs the driver that this target will be moved slowly backward and requires the driver to indicate where the "man" and the "bird" targets seem to be exactly in line. Depth perception readings are interpreted in parallactic angles, so that a driver who has normal depth perception will record a parallactic angle of $<60''$. (3) *Depth perception training*: This is done by showing the driver the exact position of the characters and the relative positions of the "man" and "bird" targets. The "man" target is placed ahead of the "bird" target as much as possible and the driver instructed to remember this fact. Then, the targets are moved backward and forward, creating a motion parallax. By repeating this procedure depth perception is developed.—*Bausch & Lomb Optical Co., Rochester, N. Y.*

Potential Indicator for High-voltage Lines

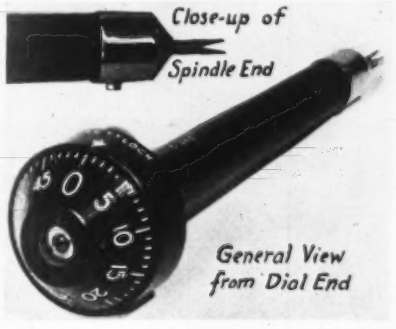
For continuously indicating (1) whether high-voltage line is energized or dead, and (2) relative phase position for synchronizing two or more lines, the new



"Hipot" Indicator consists of a coupler unit mounted in a calculated relation to the high-tension conductor, and a rectifier type d'Arsonval milliammeter. Curved metal plate on top of the coupler forms the center plate of a capacitor, the two outside plates of which are the high-tension conductor and the ground. The charge accumulated on the plate is conducted through the high impedance primary of a coupling transformer to ground. The current from the transformer secondary is led through conduit into the station control room and to the instrument. This new indicator does not depend upon connection to the insulator string or bushing but derives its energy from the electrostatic field surrounding the high-potential conductor by means of the coupler unit mounted at a safe distance. The minute currents available are amplified in a tuned transformer circuit arrangement to produce an output current of correct value and phase position for the operation of indicating instruments or sensitive relays. *Synchroscope*: Since output of coupler unit corresponds in phase position as well as in voltage value to the high-voltage line, the outputs of two units on corresponding phases of two sources of supply may be "bucked" and the resultant voltage, as indicated on the instrument, is proportional to the instantaneous phase displacement between the two supply generators. It is thus possible to synchronize across the high-tension circuit breakers. Instrument is furnished normally with two studs and no switches, but paralleling switches can be built into case and sufficient studs added. Two switches will permit synchronizing any one of four other lines to the line on which the indicator is connected.—*Roller-Smith Co., 2132 Woolworth Bldg., New York City.*

Pocket Force-measuring Instrument

Primarily designed for measuring the tension of threads in textile machinery when thread ends are not accessible, this device called "Micro-Dyn"—though essentially a spring scale—differs from straight-pull scales in that the measured unidirectional force vector is converted into a torsional effect. For example, to determine the proper setting of the thread-tensioning device in a sewing machine, it is only necessary to straddle the thread with the forked spindle and rotate entire instrument to the right (thus locking the thread in cross slots at bottom of fork) and to continue rotating until the thread is wrapped in a single layer of one or more turns. Tension of thread may then be read by lifting or pulling down on entire instrument until slipping occurs in the thread-tensioning device. The range is "0-50" and the maximum reading corresponds



to a force of 50 oz. tangential to the cylindrical surface of the spindle (as is the case when measuring the tension on a thread of negligible diameter). The device may be used as an indicator or as a maximum-registering instrument, conversion from either type to the other being effected by a thumb-lever. Principal use of maximum-registering feature is determination of breaking strength of textile threads. Attachments adapt the Micro-Dyn to numerous uses involving measurements of small forces: determinations of miniature-motor torque, electromagnet pull, relay pull, coefficient of friction, viscosity of pastes, etc.; also adjusting delicate mechanisms.—*Toledo Scale Co., Toledo, Ohio.*

Beat-frequency Oscillator

A new variable audio oscillator operating on the beat frequency principle is completely self-contained and has a direct-reading dial. Applications include measuring receiver and audio amplifier fidelity, testing speakers and cabinets for howl and using output as a sweep frequency for cathode-ray oscillograph. Fixed frequency oscillator consists of an acorn type tube operated in an electron-coupled circuit at 350 kc. Variable frequency oscillator is also an RCA-954, operated in an electron-coupled circuit over frequency range 335-350 kc, the variation being accomplished by a tuning capacitor attached to the main dial. The output of each oscillator stage is combined and fed into a self-biased RCA-955 detector which extracts the audio frequency and rejects any r-f frequencies present. The output from the detector is fed into the output amplifier: an RCA-955 fixed bias amplifier having output control in grid circuit and a

statically shielded output transformer in plate circuit. This transformer is designed to operate into center-tapped loads of 250, 500 and 500 ohms impedance. Max. output, 60 mw.; overall distortion at 60 mw. external load, <10%, at 20 mw. ex. load, <5%; calibration accuracy at 1000 cycles, 5%; power requirement, 110-120 volts, 50-60 cycles; dimensions, 9¾" × 6½" × 4½"; weight, 10¾ lbs.—*RCA Parts Div., RCA Mfg. Co., Inc., Camden, N. J.*

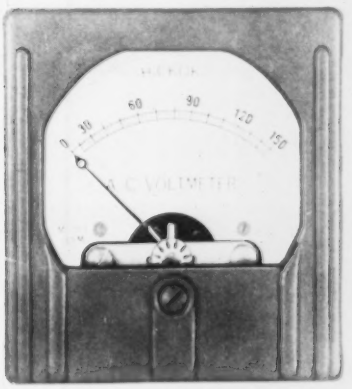
Ranger-examiner Signal Generator

Individually calibrated plug-in type coils, said to set "a new standard of obtaining laboratory accuracy at low cost," are used with the new "Model 557"

ranger-examiner all-wave direct-reading signal generator. These coils are supplied for each of the present five frequency bands from 100 to 18,000 kc, all fundamentals. Each is individually calibrated by peaking with an integral trimmer capacitor. Guaranteed accuracy <1% for broadcast and intermediate bands, 3% for short-wave bands. Instrument is said to be completely shielded for static and magnetic fields, comes in black leatherette case.—*Readrite Meter Works, Bluffton, Ohio.*

Highest Standard HICKOK of Quality

INDICATING INSTRUMENTS
ACCURATE DEPENDABLE



NEW, SQUARE CASES, IN ALL A.C. AND D.C. RANGES FOR PANEL MOUNTING. ACCURACY WITHIN 1½%.

SWITCHBOARD SIZES FOR ALL SORTS OF SPECIAL USES.

MINIATURE EDGEWISE SAVE MOUNTING SPACE, HAVE LONGER AND LARGER DEALS.

Hickok instruments will satisfy your requirements. Twenty-six years experience in the manufacture of quality precision instruments, which has enabled us to produce a trouble-free, time tested movement of highest accuracy, is your assurance that our meters will give you the very best of service.

Special ranges, movement characteristics, and designs have been developed by our engineers for use as a part of electrical apparatus, and for installation where past popular ranges are no longer satisfactory.

Over 50 different models to choose from—all sizes of round and square panel mounting, switchboard, and portable instruments for precision laboratory work. Send for our new catalogues. Your inquiries on special instrument problems are invited.

THE HICKOK ELECTRICAL INSTRUMENT CO.
10514 DUPONT AVE., CLEVELAND, OHIO

INCREASE
BOILER EFFICIENCIES
with a
REPUBLIC CO_2 METER

The latest developments in the measurement of CO_2 are incorporated in this new design of Republic CO_2 Meter.

The redesigned Republic CO_2 Meter incorporates the following important features:

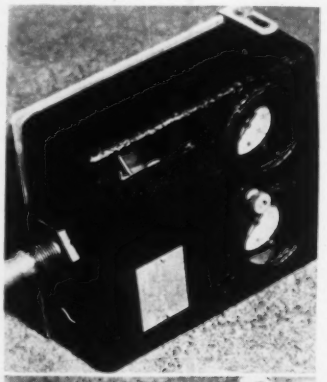
- The CO_2 is measured by the Orsat method.
- Meter readings are free from the effects of temperature variations.
- The meter has a gas suction powerful enough to draw 14 inches of mercury. This eliminates the possibility of stoppage in the sampling line.
- The Republic Meter is driven by a fractional horse power motor and no water is required for its operation.
- A filter in the gas line removes all SO_2 before it reaches the meter.
- The large caustic tank holds enough potash to last from 4 to 6 months.
- The simplicity of the meter and its rugged construction eliminates the necessity for frequent servicing and adjusting.
- Hundreds of companies have used the Republic CO_2 Meter for many years and recognize it as standard for the mechanical measurement of CO_2.

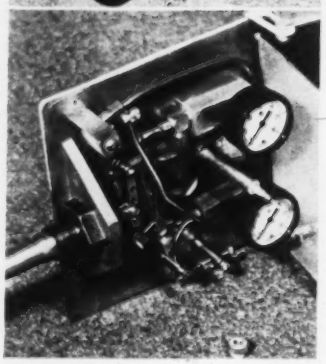
Data Book 403, just published, gives complete description.
Mailed on Request

REPUBLIC
FLOW METERS CO.
2249 Diversey Pkwy., Chicago, Ill.

Rigid-stem Air-operated Temperature Controller

Total range extends from —100°F. to 900°F., the desired working range being obtained by (1) a resetting screw which determines its mid-point, and (2) a sensitivity adjustment which determines its width, *i.e.*, the number of degrees differential at stem between open and closed positions of controlled valve. Hence, this new instrument has been designated the H & B "All Range" Temperature Controller. Stem is a tube of KA-2 alloy, of which the total expansion is used, central rod having a negligible temperature coefficient of expansion. For best results,

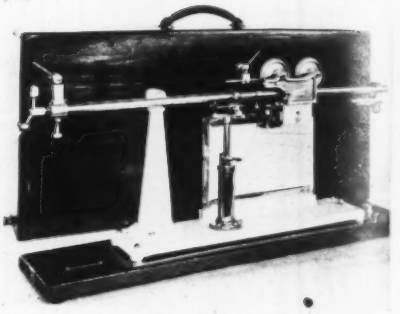




therefore, full length of stem should be exposed to temperature to be controlled. Operating medium is clean air or gas at 15 lbs./in.^{2} constant pressure, quantity required for operation of diaphragm-motor valve being <8 ft.^{3}/hr. One feature not found in other air-operated controllers, it is said, takes the form of a "throttling needle" whereby the conventional flapper is modified into a slow-bleed device. This, in connection with lever-length adjustments, makes it possible for user to regulate speed of operation of diaphragm-motor valve. Conversion from direct-acting to reverse-acting requires only reversing one lever. Safety provisions in design and construction prevent damage to controller parts in event of large sudden temperature change at stem.—*H. O. Bushnell, 520 Anderson St., Los Angeles, Calif.*

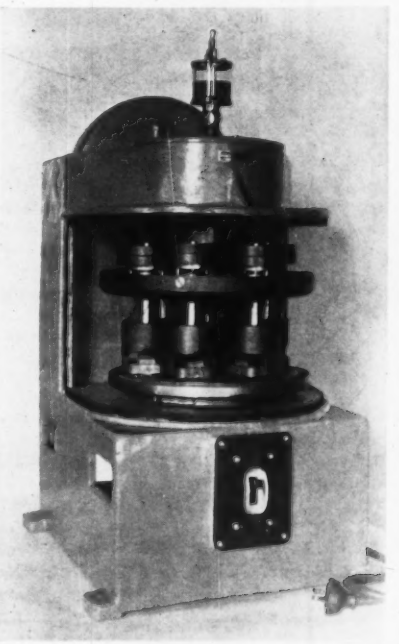
Autographic Elongation Tester For Yarns, &c.

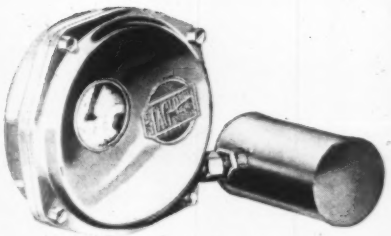
Tensile and elongation tests of fine yarns, etc., are semi-automatic, and their results recorded automatically, with new "Model I-P-5 Incline Plane" testing machine available in dual capacities of 0-250 & 0-500 g., or 0-0.5 & 0-1 lb. Drive is by mercury dashpot. Stylus is commercial fountain pen. Initial tension device assures placing all specimens under identical conditions. Standard machine takes samples <10"; may be specially arranged for longer specimens. Furnished with all accessories in carrying case.—*Henry L. Scott Co., 101 Blackstone St., Providence, R. I.*



Metals and Minerals Polishing Machine

New model Graton-Vanderwilt six-holder polishing machine, in connection with Graton-Vanderwilt method of specimen production, is said to achieve combination of (1) surface sufficiently flat for simultaneous sharp focus of all components in field of high-power microscope, and (2) complete absence of "relief" at grain boundaries when components are of different hardness. New machine is a completely self-contained unit; its chief design feature is effective enclosure of polishing laps and specimens to prevent scratches by random particles of abrasive dusts, with an oil drip feed to keep laps at proper state without opening guards. Guards are transparent. It is said that the various stages of coarse and fine grinding can be done on one machine but it is added that in each laboratory at least one machine should be reserved for final polishing. Complete time of grinding and polishing of ore specimens, by methods advocated, is 1½ to 2 hrs. for six specimens. Machine uses Bakelite mounted specimens (mounting can be done by makers) and, in case of friable materials, impregnated specimens.—*Manu Instrument Corp., 10 Arrow St., Cambridge, Mass.*



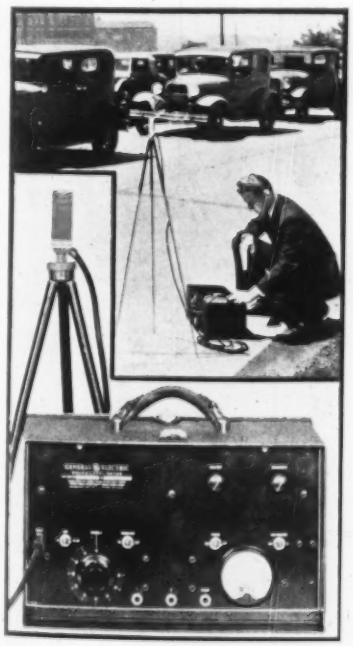


Miniature Traveling Recorder

For recording on a 6-hour or 12-hour chart the temperature inside a bottle or can of beverage as it passes through a pasteurizer or other processing apparatus, this new size traveling recorder has been developed for use in pocket type pasteurizers and other equipment where space is limited. Chart size, 4"; dimensions 16½" × 6½" × 3"; three styles of connections for the latest standard bottles and cans.—*C. J. Tagliabue Mfg. Co., Park & Nostrand Aves., Brooklyn, N. Y.*

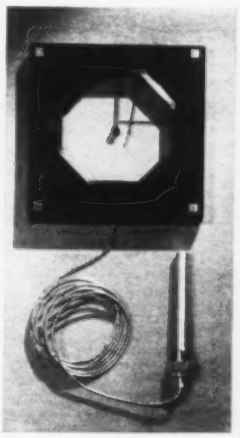
Sound-level Meter

A new sound-level meter has been developed to provide performance in accord with the newly adopted ASA standards. Special precautions are said to have been taken to make the amplifier unit suitable for use in the neighborhood of electrical machinery where stray magnetic fields are common. The microphone is a small, nondirective, piezoelectric type, with practically flat frequency response <8000 cycles, shielded against stray electric fields, and unaffected by stray magnetic fields such as those usually surrounding electrical machinery. The 5-stage amplifier is resistance-transformer coupled and has special small-size, low-drain tubes mounted in shock-reducing sockets. A switch permits the selection of either a flat-frequency response to measure sound intensity, or a weighted response which approximates that of the ear at a loudness of 40 db. Indicator is calibrated to read in db above the standard reference level of 10^{-16} watts/cm.^{2} at 1000 cycles. Range is 30 to 120 db. Jacks are provided in a 500-ohm inter-stage circuit to permit use of auxiliary equipment (analyzer, vibration velocity unit or special filtering and control circuits). A receptacle is provided for connecting external batteries where instrument is to be used on permanent location. A simple mouth-blown calibrating unit serves for overall field calibration. Factory calibration is obtained by placing the microphone in a standardized sound field. Outfit comprises microphone, tripod, calibrating unit, and batteries; is contained in a metal case 15¾" × 9½" × 8¼"; carrying weight approx. 39 lbs.—*General Electric Co., Schenectady, N. Y.*



Recording Thermometers

Developed especially for industrial service, these 10" chart recorders have interchangeable thermal systems readily removed and replaced in the field, and



the helical pressure-spring of each thermal system is "cartridge-sealed" for complete protection against dirt, moisture and damage from handling. Absence of multiplying linkages is another feature, helix directly driving shaft of pen-arm and zero adjustment being made by rotating entire helix within cartridge. This rotation is effected from front of instrument panel by means of a screw-driver inserted in slot on face of an 8-tooth pinion meshing with a 16-tooth gear, to hollow shaft of which one end of helix is attached. (Pinion and gear are exposed but inner end of gear hollow shaft is within sealed cartridge.) Standardized forms of bulbs are available for measuring flue gas temperatures, average temperatures of large areas, temperatures in open vats or tanks, closed tanks under pressure or vacuum, pipe lines, refrigeration systems, drying rooms, ovens, kilns, air ducts, insulated tanks, etc. 39 ranges are available between limits of −20°F. and +1000°F., minimum length of any chart range being 90°F. or 50°C. All charts are evenly graduated. Max. tubing length is 200 ft. and instrument is said to be so compensated that effects of temperature change on capillary may be disregarded. Instrument is mounted on a 16" × 16" black steel panel; aluminum bezels; dust-proof door; automatic pen lifter and non-removable chart knob; electrical or mechanical clocks. One, two or three records may be obtained on a single chart; records other than temperature may be flow, CO_2, draft, pressure, etc.—*Republic Flow Meters Co., 2240 Diversey Parkway, Chicago, Ill.*

GM

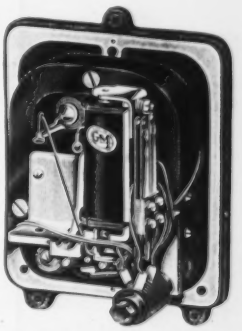
SENSITIVE D'ARSONVAL RELAYS—TYPE "S"

Sensitivity—⅛ Micro-Watt (each side of center).

Coil Resistances, 12.5, 50, 200, 540 ohms.

Contact capacity, 0.1 Amp. at 10 volts.

Normally supplied with auxiliary electromatic relay to increase contact capacity. See illustration. Also furnished with special energy transfer circuit to increase contact pressure.



Type SEA Relay, including a sensitive "S" Relay, auxiliary "E" Relay with 2 amp. non-inductive 110 volt A.C. capacity and rectifier operating on 11 volts A.C. Size, with cover 5¼x3⅛x6⅜" high.

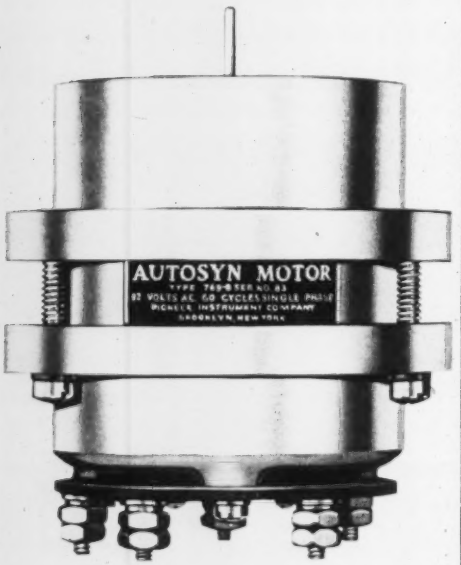
The Type "S" Relay is a sensitive D'arsonval instrument having a moving coil of large size. The pole pieces, core and permanent magnet are all of ample proportions resulting in large mechanical torque per unit of power input to the coil. Because of the large size of the movement parts, it has been possible to provide an unusually long air gap between the pole pieces, coil and core, which greatly reduces the tendency for the armature to stick or be obstructed by magnetic dust or particles of dirt. This feature itself has made the "S" Relay a very useful unit for industrial and control purposes where other sensitive types of relays have failed because of small mechanical clearances.

Write for Catalog

G-M LABORATORIES INC

1732 Belmont Avenue, Chicago, U.S.A.

"AUTOSYN
Self-Synchronizing Motor



TYPE 769B
ACTUAL SIZE

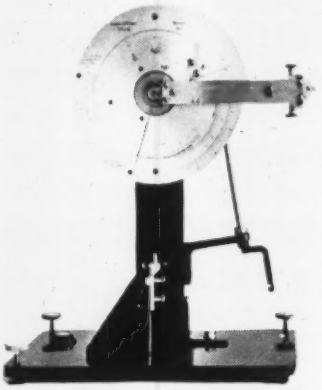
Type 769B, the smallest self-synchronizing motor manufactured, is suitable for a wide variety of remote indication applications. Slight movements of sensitive elements such as diaphragms and Bourdon tubes may be instantly and accurately transmitted to duplicate or triplicate indicators.

Size—2⅜" diameter x 2⅜" long
Weight—10 ounces
Current—.16 amperes
Voltage—32V. A.C.—60 cycle
Power consumption—2 Watts
Heat Rise—15°C.
Peak Torque—40 Gram. Cm.
Maximum lag—approximately 1½ Degrees
Shaft Diameter—1/16"
Ball Bearing Equipped

PIONEER INSTRUMENTS
Pioneer Instrument Company, Incorporated
BROOKLYN, NEW YORK
Subsidiary of the Bendix Aviation Corporation

Tester for Plastics

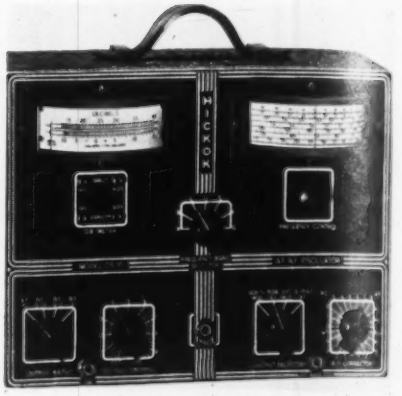
New "Dynstat" testing machine has been especially designed for test procedures recommended by German gov't materials-testing bureau in report by



Schob, Nitsche and Salewski which disclosed erroneous results of applying classical hard-material laws and ordinary procedures to mechanical testing of plastics. "Dynstat" is said, moreover, to permit making every mechanical test to which makers and users of insulators and other molded materials attach significance. For determining impact strength two hammers permit tests of 0-10 cm./kg. and 10-20 cm./kg. working capacity, from drop angle of 60° or 90°. For the bending-strength tests the ranges are 0-5, 0-9.8 and 0-40 cm./kg. For determining impact bending strength, specimen is placed on an anvil of special design and a pendulum is allowed to fall free from a pawl. An idle pointer on the left then indicates the rise of the pendulum on the corresponding scale after the impact and provides a reading of the energy absorbed. For static bending test, specimen is clamped on rotation axis of machine, subjected to bending by turning center part of scale dial, to which it also is secured, by means of a crank and worm gear. This causes pendulum to move to the right, and value of bending movement is measured to the right-hand idle pointer.—*Testing Machines, Inc., 400 W. 42th St., New York City.*

Radio & Audio Oscillator

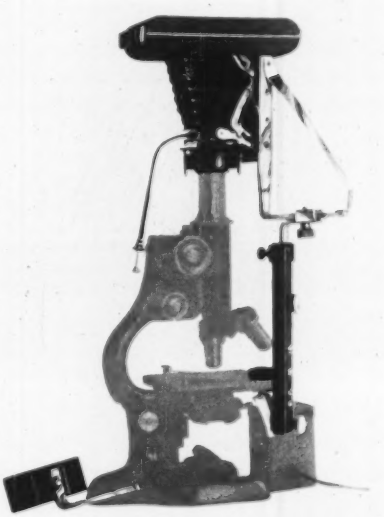
Said to be the only popular-priced meter-equipped oscillator outfit available, this instrument comprises two oscillators, a 2-range decibel meter, output ratio-control, built-in power supply, r-f. corrector and other auxiliaries. *Tubes*: types 41, 6C6, 6D6 and 1V, latest 6-volt heater type, are operated below their normal rating. *Circuit*: The variable r-f. circuit utilizes the type 41 pentode as an electron-coupled high-stability r-f. oscillator. This oscillator circuit is continuously variable from 85 kc. to 25 Mc. in six ranges, each marked on main tuning dial and extending over 7" of scale length. A type 6C6 is used interchangeably, as a negative resistance oscillator, at 400 cycles or at a fixed frequency of 450 kc. When used as the 400 cycle oscillator, its output may be used to modulate the r-f. carrier at approx. 50%. When used at 150 kc. it is used to beat against the main oscillator to provide a variable a-f. from zero to approx. 11,000 cycles. A type 6D6 tube is used as a demodulator mixer for mixing the outputs of the two oscillating sections, and providing a decoupling amplifier to isolate the input from the output circuit. It also acts as



an amplifier and amplifies output to 3 volts. The type 1V tube is a half-wave cathode type rectifier and is used to rectify the a.c. supplied by the secondary of the power transformer. *R-f. corrector* permits micrometer band spreading; with calibration data supplied, accuracy of oscillator becomes better than 0.2%. An external electronic frequency modulator is available for oscillograph use. Dimensions 11" × 9" × 5¼". *The Hickok Electrical Instrument Co., 10531 Dupont Ave., Cleveland, Ohio.*

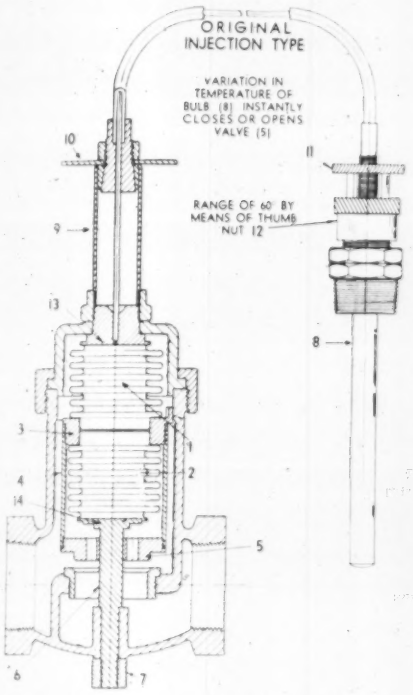
Simplified Outfit for Photomicrography

Any microscope user, with casual knowledge of amateur photography, can make records of his work by employing new "Microdak." The outfit consists of a camera using 2¼" × 3¼" roll film and having a fixed-focus lens and a shutter with provisions for bulb and time exposures; a light-lock to shield the microscope eyepiece and camera lens; a bracket for holding the camera; a support for the camera and bracket, which fastens to the stage of the microscope; and a counterweight that attaches to the microscope base. In making photomicrographs with "Microdak," subject is illuminated and microscope focused in usual way, with a relaxed eye. Light lock then is placed over eye-piece and camera so located that lens will assume position occupied by eye in focusing. An exposure of proper length is then made. No dark-room being required, photomicrographs can be made in ordinary shops, offices and laboratories.—*Eastman Kodak Co., Rochester, N. Y.*



Self-operating Controller

Principle, characteristics, and construction features of original model have been described here (see *Instruments*, May 1934, page 97). While retaining principal features of the Johnson Regulator, the National Self-Acting Temperature Regulator has been improved and simplified. Spacer (9), formerly Bakelite, is now made of Monel tubing. This controller has proved itself to be so sensitive that manufacturer has reduced bulb dimensions to $\frac{5}{8}$" diam. × 8" to 12" long with 1" s.p.t. union connection. These bulb dimensions still further reduce the low thermal lag and are said to make possible close control on installation heretofore considered difficult. New model has a range of 60°F., can be supplied to control any temperature between 50° and 275°F.—*National Instrument & Regulator Co., 1812 S. Michigan Ave., Chicago, Ill.*



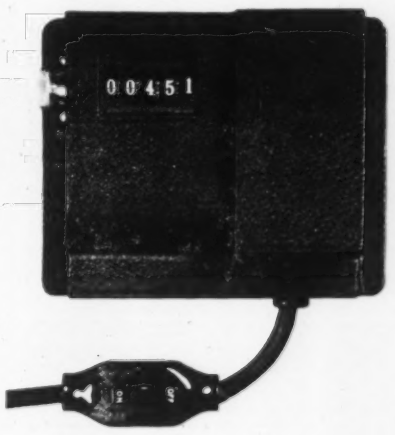
Sensitive Relay

Designed to cover the field between the ultra-sensitive type of relay, with its low current-carrying capacity, and the heavier, service type of relay requiring

a large input wattage, new "Type 1-A," d-c. input, is jewel-mounted and balanced to operate in any position; its movement is light in weight and can be adjusted to respond well to about half of the rated 4-mw. minimum field input. Its hairspring and contacts will carry 1 amp. if sparking be minimized. Mounted on a 5-prong plug which fits the standard tube socket, it can be removed or shifted easily. This type of mounting, together with the visibility of its movement, is said to make the relay particularly suitable to experimental work, as well as to permanent installation in supervisory and control circuits.—*Sigma Instruments, Inc., Belmont, Mass.*

Elapsed-Time Register

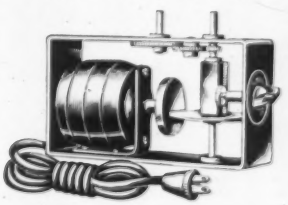
New "Tymeter" is of the single-register type: a five-digit cyclometer registering total time during which circuit was closed. It is available in three models: (1) minutes and hundredths, (2) seconds and tenths, (3) seconds and hundredths. In common with other such devices, registration stops when circuit is opened



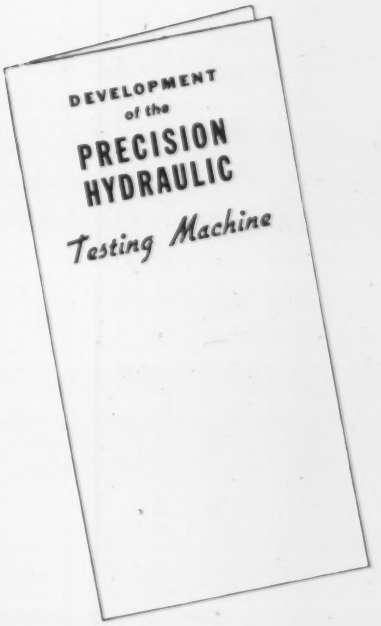
and resumes automatically when circuit is re-closed. A manual switch (see illustration) permits subtracting outages such as "machine running idle." Standard models have synchronous motors designed for 110-volt 60-cycle supply. Others can be furnished. Case is $5\frac{1}{2}$" wide, of die-cast aluminum with black crackle finish.—*M. J. Stillman Co., Inc., 116 So. Michigan Ave., Chicago, Ill.*

1/100-hp. Variable-speed Miniature Motor & Drive

Designed primarily to provide a synchronous scanning system with maker's neon oscilloscope tube, new "Senco Vari-Speed Drive" is equally applicable to



stroboscopes, timing and control instruments, cathode-ray tube sweeps, laboratory life tests, etc. Speeds from 0 to 1000 r.p.m., said to be constant to <1% drift, are available by turning a calibrated dial, a 10:1 reduction being used for slow speeds. Unit is powered by a 1/100-hp. shaded-pole motor; average torque is 1 in.-lb. All bearings oilless. Dimensions, $8\frac{1}{2}$" × $4\frac{1}{2}$" × $3\frac{1}{2}$"; weight, 10 lbs.—*Saudt Engineering Co., 4250 Lincoln Ave., Chicago, Ill.*



YOUR COPY IS READY...

Here's a history of the development of hydraulic testing machines which every testing engineer should have. It describes accurately the various types of indicating units used to date and the reasons for the widespread adoption of the modern precision hydraulic machine. Write for your copy —it's free.

RIEHLE DIVISION

AMERICAN MACHINE AND METALS MANUFACTURING CORP.

•

100 SIXTH AVENUE
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RIEHLE DIVISION
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Please send me copy of "Development of the Precision Hydraulic Testing Machine."
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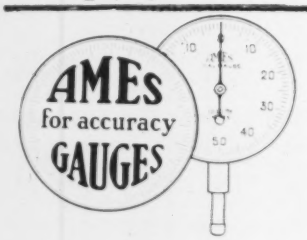
AMES GAUGES

have perfect teeth



Dial Gauges must have perfect teeth to be accurate. Perfect in shape, smooth and free from burrs. With a gearing ratio of 10 to 1, the slightest error is thrown up big on the dial.

Milled teeth are true in form, do not vary, have no radial grooves and require little brushing and polishing for burr removal. Machines of exclusive AMES design make three cuts across pinion and wheel blanks, cutting one tooth at a time —a sawing cut, roughing, and then a finishing cut. After burr removal, leaf polishing machines complete the process.

More costly to make them that way, but AMES Gauges are notably accurate and durable.

B. C. AMES CO.

WALTHAM, MASS.

The Burling

HEAT CONTROL

Has:

SIMPLICITY
ACCURACY
ADAPTABILITY
LOW FIRST COST
PERFORMANCE

MODEL D

Normal temperatures 50-1400° F. Mechanism not injured by excessive heat.—Adjustable range made to suit. Snap action switches rated 10 Amps, 110 Volts A. C.

Control very delicate, if required. Send us your inquiry. The answer will interest you.

Burling Instrument Company

239-243 Springfield Ave. Newark, N. J.

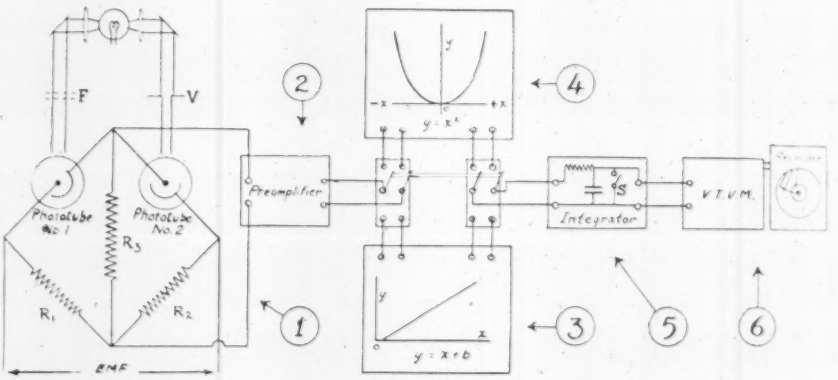
Thread Diameter Continuous Recorder and Grader

An automatic recording photometer developed primarily for determining the unevenness, or variation in diameter, of raw silk thread, is hence known as the "Evenometer." Up to now, evenness estimations of the thread (about 48 microns diam.) have been made by eye or by weighings of numerous small skeins. With the Evenometer, deviations in thread diameter are measured photoelectrically and then passed on to amplifiers of different characteristics, electronic circuits performing mathematical operations and reporting the average diameter and standard deviation in microns.

Raw silk is wound in the customary manner, 100 threads per inch, around a seriplane board about 5 ft. long and 1½ ft. high, divided into 10 panels, each 5" long and holding 500 m. of a test sample. From one end of the board to the other runs a slot through which a beam of light is directed so that the rays which pass between the threads is built up across the capacitor proportional to the output current and always in a positive direction. This integrated bridge unbalance value is taken off the condenser at regular time intervals by the vacuum-tube voltmeter (6) and the value is recorded in microns on the chart of a sensitive watt-second meter. Thus it can be seen that the recorder registers

$$\frac{\int_0^{n_o} (x_s - x_1)^y \, du}{n_o} \qquad (1)$$

where x_s = diameter value of the standard, x_1 = any individual diameter measurement, n_o = number of individual measurements in scanning the sample, and $y = 1$ when amplifier No. 3 is used, $y = 2$ when amplifier (4) is in the circuit. This expression, in statistical mathematics, represents variance; hence it is only necessary to choose the proper value



fall on the cathode of phototube No. 1, whose output is proportional to the amount of incident light. Since the number of threads wound in a given length of the seriplane board is always the same, the light spaces between the threads will vary inversely as the thread diameters. Since the light which falls on the phototube must pass through the intervals, the resultant phototube current is an accurate function of the thread diameter. The light source and phototube are mounted on a constant-speed worm-driven carriage. As the scanning beam moves along the slot, the thread diameter measurements are summed up and recorded on a chart, as follows (referring to diagram):

Evenometer consists of six basic units. No. 1 is a phototube bridge circuit where $R_1 = R_2$. Bridge balance is obtained by adjusting light valve V until same amount of light falls on phototube 2 as is passed through a standard transmission sample F to phototube 1. After this adjustment, phototube 2 serves as the standard cell, and the samples of raw silk threads are substituted in place of F. When variations in thread diameter cause a change in the light falling on phototube 1, bridge becomes unbalanced, effecting a voltage drop across R_3. This voltage is amplified by the preamplifier (2) and passed on either to linear amplifier (3) for determining average size, or to square-law amplifier (4) for determining the standard deviation. The output of either No. 3 or No. 4 is coupled to the integrator (5) where a voltage of standard (x_s), and amplifier characteristic (y), in order to have the recorder give a direct reading of the average diameter size, or the square of the standard deviation. These statistics offer the most pertinent information on the evenness quality of the yarn and afford a sound basis for predicting the quantity of seconds to be expected in the finished fabric. The Evenometer is said to be the first instrument to make rapid accurate diameter measurements of large quantities of raw silk without introducing errors caused by the resiliency and inhomogeneous character of the yarn, and without destroying the samples.—*United States Testing Co., Inc., 1415 Park Ave., Hoboken, N. J.*

Photoelectric Cell

A new photoelectric cell of the caesium-argon type, known as Cetron type CE-20, has been designed especially for use with 16-mm. projectors and other applications where a "small but efficient" photocell is required. Dimensions: 2" from bottom of base to top of bulb, width 11/16"; cathode concave 5/8" high, ½" wide; anode rectangular ½" square. Base, special 3-prong. Among claimed advantages are high sensitivity, low microphonic characteristics and compactness.—*Continental Electric Co., St. Charles, Ill.*

The Measurement of Hardness

By S. R. WILLIAMS
Professor of Physics, Amherst College, Amherst, Mass.

IT is commonly stated that the hardness of a material is measured by its resistance to penetration. Such a definition brings up the picture of a penetrator and a penetratee.

How hard is a snow drift? The answer lies at hand: the resistance which it offers to the penetration of a snow plow. On what does this resistance depend? Upon four factors (see Fig. 1):

1. In the first place it will be some function of the angle ϕ formed by the two wings of the snow plow.

2. As the point goes into the snow, the crystal particles must be torn apart. The harder it is to pull the crystal particles apart, the greater will be the resistance to penetration of the snow plow.

3. The movement of the snow plow forward into the snow pushes crystal particles of the snow over one another. This gliding movement offers a frictional resistance to penetration which may correctly be called the internal friction of the material.

4. Finally, the snow will slide over the surfaces of the wings of the snow plow. If the surfaces are rusty or rough it will not slide easily, and thus another factor is brought into play to increase the resistance to penetration. A rusty plow for turning over soil also illustrates this fourth factor.

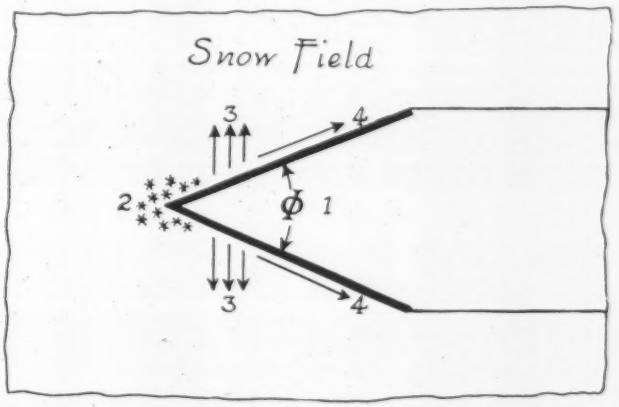


Fig. 1. Two planes at an angle ϕ are forced through a snow drift. Resistance to their progress depends upon at least four factors.

One may express these various terms in a symbolic equation which could become an actual equation did we but know all the factors involved. The resistance to penetration of the snow plow may thus be expressed:

$$R = f_1(\phi) + f_2(m_1 m_2/d^2) + f_3(\mu_1 p) + f_4(\mu_2 p)$$

where the subscripts of the fs correspond to the numbers attached to the factors on which R depends.

It will be seen that the first and last factors on which the hardness R depends are really properties of the penetrator and not of the penetratee. It is the hardness of the latter in which we are interested. The scratch method, the steel ball and cone indenters used in measuring hardness have these same factors involved.

To a physicist it always has seemed unfortunate to try to measure a property of a substance which becomes so hopelessly involved with the physical properties of the measuring tool. It seems equally futile to go on trying to improve a method which continues to have these inherent difficulties. Just to show the difficulty of the situation, one needs only to allow the snow plow to stand around a few days and rust, when it will be found that the snow drift has increased its hardness.

As an analogous experiment, a test plate was used under a steel ball indenter, first when the surface of the test plate was clean and dry, and again when oil covered the surface. Some materials increased their hardness as much as 4% when oil covered the surface. No one can imagine for a moment that the oil changed the hardness of the test plate. It was a difference due to the fourth factor in the above equation. Oiling the surface allowed the metal in the test plate to flow plastically under the steel ball without breaking. Whereas, if the surface is clean and dry, the surfaces of the ball and the test plate stick; the particles of the test plate tear apart, so that there is not the elastic comeback on release of load that there is when the lubricated surface is unbroken. An outstanding example of this is shown in soft rubber. The comeback after release of load makes rubber appear to be almost infinitely hard, which, of course, we know is not true. It comes back to saying that in all of the penetration methods, scratch or otherwise, the hardness as measured is going to depend upon whether the indentation is through plastic or brittle processes.

The Indian, by a trial and error method, understood this centuries ago when, by means of a bone tool, he could chip the flint stone into an arrow head. He knew that he could disrupt the stone by a shearing stress, but could never fashion the stone plastically with a soft tool of bone.

It would seem that there has not been enough of a distinction made between hardness as measured plastically and that measured against a shearing strain. It is well known that in Moh's scale of hardness, it is easy for a beginner to make a soft stone scratch a harder one. It is a repetition of the Indian scratching a harder substance with a softer one. He shears off a portion of the harder substance by means of a softer tool.

If, in the equation for R, one could eliminate factors 1 and 4 in measuring hardness, it is interesting to note that the factors left are those involved in the elasticity of stretch at the yield point. Factor 2 deals with the tearing apart of the particles which constitute the substance examined. Factor 3 depends upon the way in which these particles slip over one another as they move, i.e., the internal friction between the particles constituting the material under test: μ represents the coefficient of this friction and p is the pressure applied. Both 2 and 3 are inherent in the specimen tested. These two factors are just those which come into play when a body subjected to a pull reaches the elastic limit and the yield point is attained. In other words, could such a test be employed, the yield point or the tensile strength would come more nearly to being a measure of hardness as now understood than any other property of matter. Such properties are inherent in the substances to be measured and not in the instruments of measurements. In arriving at this point of view, one must not forget that in doing so, the conclusion has been reached by assuming at the

start that hardness is measured by resistance to penetration.

Although the writer thus appears to criticize indentation methods for measuring hardness, no one is more aware than he of the wide use and utility of our present-day hardness testers. For manufacturers, hardness tests offer a quick method for judging the suitability of materials for a certain use, or for maintaining certain standards in the materials adopted. The resistance to penetration rests upon the difficulty of pushing the granules composing a body to one side and getting them out of the way of the penetrator. Hardness seems to rest upon the inter-atomic, inter-molecular forces which hold these particles together in a solid. If atoms of all substances are made up of electrons and protons, then the same kind of forces are holding them together and the overcoming of these forces is a measure of hardness. Such considerations seem to make hardness cut across the composition of materials and rest largely upon the means whereby the forces holding together the common granules can be varied.

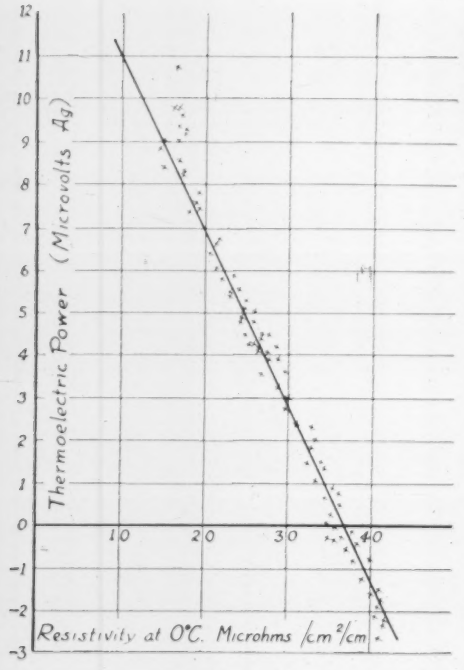


Fig. 2. Relation between thermoelectric power and resistivity as found by Barus and Strouhal.

It seems, therefore, that a basic study might be launched in which those physical properties dependent upon the same factors might be related to hardness. It is conceivable that out of such a study might come methods for arriving at values of hardness quite as simple as the present and bearing more directly upon hardness than does the penetration method.

The author levels no criticisms against the modern instruments used in so-called hardness testing when their objectives are correctly understood. They are not hardness testers but measures of suitability of material for specific purposes and as such are wonderful machines. However, for one who is trying to find out if there is such a physical property as hardness, the data given by these machines can only lead to confusion.

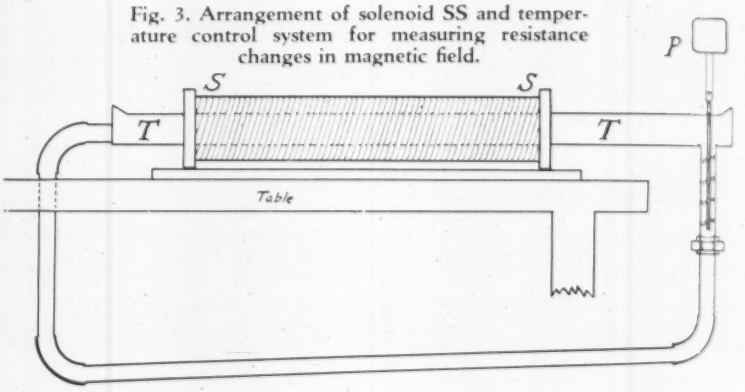
The real criticism which the author has to offer is, that physicists who study these facts have not taken as much interest as they should in the problem of hardness and its measurement if such a physical property exists.

With the aim of "putting physics to work in industry" a joint conference was recently called by the American Institute of Physics and the National Research Council. To the writer, here is an outstanding problem in which chemists, metallurgical engineers and physicists could do a fine piece of coöperative work.

Magnetic fields can change the forces between the particles which go to make up ferromagnetic substances. One line of investigation would lie along the relations between magnetism and hardness.[1]

More than fifty years ago Barus and Strouhal[2] carried on an extensive investigation on "The Electrical and Magnetic Properties of the Iron-Carburets." These investigators studied the thermoelectric power and the resistivity of a large range of iron and steel, varying from glass hard at one end of the series to the softest iron obtainable at the other. If the resistivities of the rods were plotted against their thermoelectric power, all of these points fell on a straight line (see Fig. 2) indicating, as the authors pointed out, that there was some inherent relation between hardness, on one hand, and thermoelectric power and resistivity on the other. It at least points out that hardness and the last two mentioned physical properties have to do with internal forces and are not influenced by the measuring instrument. Unfortunately, Barus and Strouhal did not have modern methods for measuring hardness. They had to depend upon color indications in hardening and annealing.

Fig. 3. Arrangement of solenoid SS and temperature control system for measuring resistance changes in magnetic field.



With our modern methods for measuring penetration by means of a steel ball penetrator, it seemed desirable to review this early work of Barus and Strouhal and at the same time extend their studies to other allied physical properties. There is a need for the accumulation of a great deal of information regarding various physical properties and their relations to hardness. With this in mind, the following short study has been made of a series of steel rods with varying degrees of carbon content. Their resistance and change in resistance with varying longitudinal magnetic field have been compared with their hardness as measured with a Rockwell tester.

The method employed in measuring the resistivity and the dr/R in a magnetic field was the same as that employed by Williams and Sanderson[3] in a similar study of a series of nickel rods having different degrees of hardness attained by cold rolling.

Fig. 3 shows the long copper trough, *TT*, in which the rods were placed and maintained at a constant temperature of 35°C. by circulating oil whose temperature was kept at 35°C. by a thermostat control. The temperature

[1] S. R. Williams, Mechanical Hardness Influenced by Magnetism and Measured by Magnetostrictive Effects. *Transactions A.S.S.T.*, Vol. [illegible], Aug. 1933, page 74.

[2] C. Barus and V. Strouhal, The Electrical and Magnetic Properties of the Iron-Carburets, *Bulletin U. S. Geological Survey*, No. 14, [illegible].

[3] S. R. Williams and R. A. Sanderson, Changes in Electrical Resistance Due to Magnetism and Hardness, *Physical Review*, Vol. 37, [illegible], page 309.

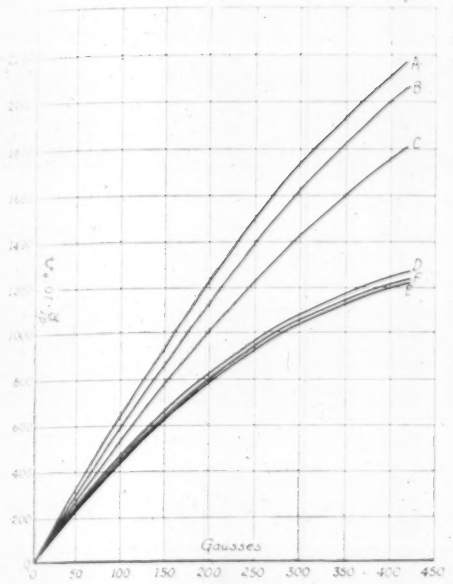


Fig. 4. Change in resistance with varying field strength.

Fig. 5. Change in resistance with varying field strength in which field has been extended to 750 gausses.

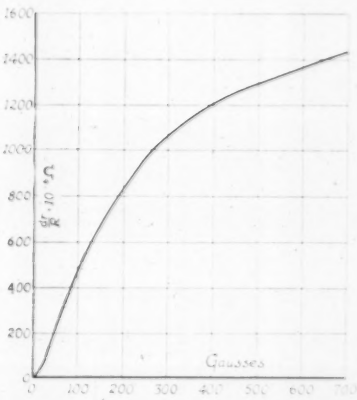


Fig. 6. Relation of resistivity to Rockwell number.

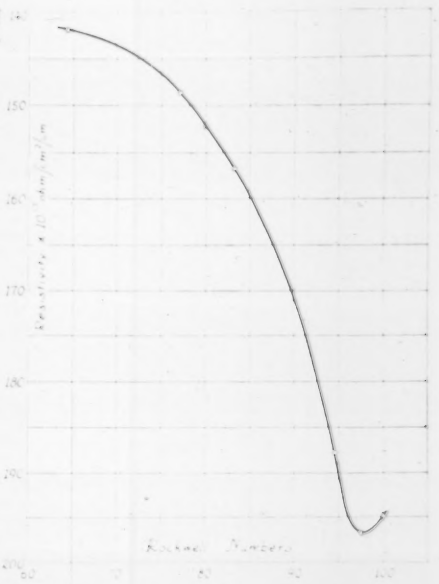


TABLE I

Rod	Carbon	Manganese	Phosphorus	Sulphur	Hardness
A	0.11	0.49	0.010	0.039	64.2
B	0.31	0.53	0.012	0.039	77.1
C	0.49	0.41	0.012	0.033	83.1
D	0.69	0.48	0.019	0.033	94.5
E	0.91	0.44	0.023	0.027	97.3
F	1.11	0.42	0.019	0.036	99.9

TABLE II. COEFFICIENTS OF RIGIDITY

A	$n = 8.166 \times 10^{11}$	D	$n = 7.980 \times 10^{11}$
B	$n = 8.178 \times 10^{11}$	E	$n = 8.045 \times 10^{11}$
C	$n = 8.169 \times 10^{11}$	F	$n = 8.124 \times 10^{11}$

Fig. 7. Torsion lathe for measuring coefficients of rigidity.

of 35° C. insured that when the heating coil was turned off the oil would radiate to the room, whether the season was winter or summer. The pump P kept the oil flowing steadily around the system. A double Kelvin bridge was used in measuring the resistance and the change in resistance produced by the magnetic field of the solenoid SS as its field was increased from zero up to 450 gausses. There were three samples of each carbon content so that 18 rods were measured in all. The rods were designated as follows: A_1, A_2, A_3, B_1, B_2, B_3, C_1, C_2, C_3, D_1, D_2, D_3, E_1, E_2, E_3, and F_1, F_2, F_3. The A rods were the softest while the F rods were the hardest as measured with the Rockwell tester. All were given the same heat treatment. Some of the characteristics of the rods are given in Table I.

The values of resistances and change in resistance are the averages of the observations taken on the three rods of each carbon content.

Fig. 4 shows how the change in resistance per ohm varies with the field strength in the solenoid, SS, Fig. 3. Fig. 4 will indicate that if the field strengths in the solenoid are increased the curves for dr/R tend to become asymptotic to the axis of field strength.

In the general discussion it was pointed out that the equation for hardness indicated that the tensile strength or the elastic limit might measure hardness. The question was raised in this study, does the coefficient of rigidity have any relation to hardness? It was a simple matter to study the coefficient of rigidity of these rods and so they are tested by the method shown in Fig. 7. Two mirrors, M_1 and M_2, were attached at the ends of each rod in such manner as to eliminate any error due to slip in either chuck of the torsion lathe. Furthermore, the mirrors were attached to each rod by sharp needle points, so that the distance between the mirrors, or the length of the rod twisted, could be accurately measured. A telescope and scale set at a distance of >2m from each mirror gave a precise method for measuring the angle of twist.

Only small torques were applied, so that at no time was the elastic limit exceeded. In spite of the large change in the Rockwell numbers, practically no change occurred in the coefficient of rigidity of these rods. Table II gives the values of n for the series of six rods. It is in the permanent deformations that one begins to find a measure of hardness. It is here that the definition of hardness—resistance to permanent deformation—finds its meaning.

This note seeks, therefore, to emphasize the need for simple studies on the relations between hardness and those physical properties which have common factors.

There is under way in this laboratory an extensive study of all sorts of materials, whose hardness has been varied by every method available, to see if the relations found by Barus and Strouhal extend to other substances beside those of iron and steel. Fig. 6 shows the relations between the resistivities of these same rods and their Rockwell numbers.

During the World war the National Research Council considered the study of hardness and hardness measurements an important problem. A special committee was set up for its consideration. The fact that the committee ceased to function because of lack of funds in no way detracts from the importance of the problem.

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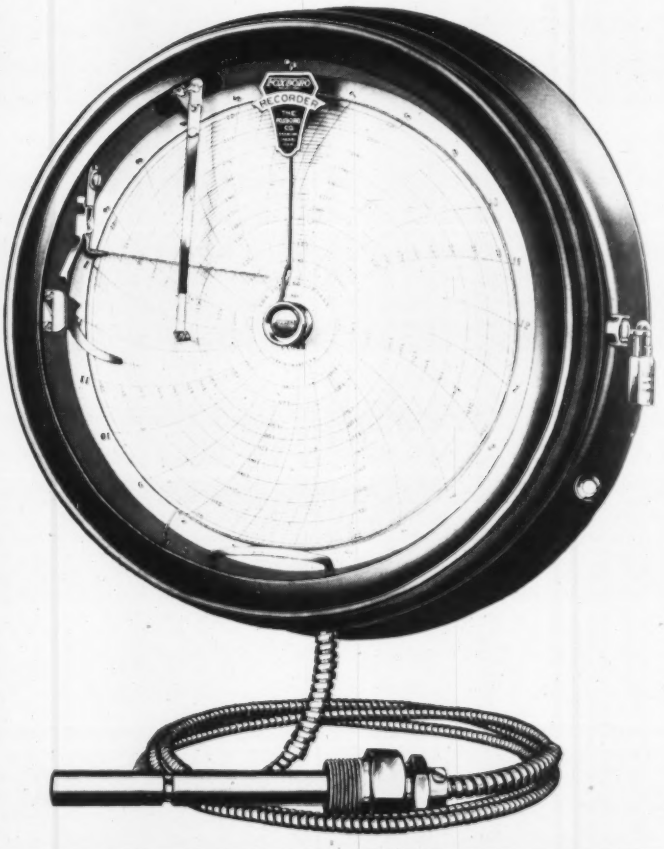

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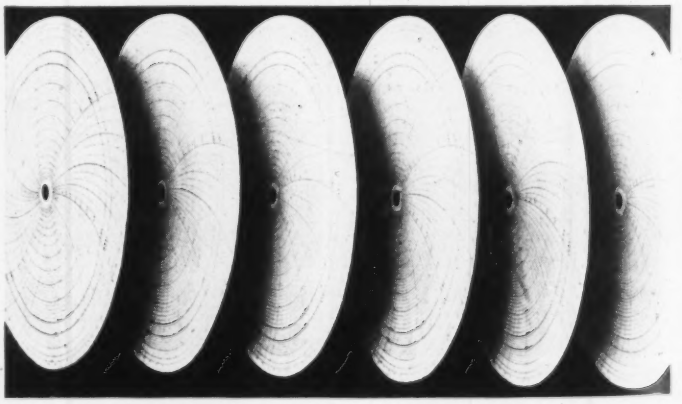
RESPONSIVENESS CHART

INSTRUMENT	TIME TAKEN TO COVER EQUAL PORTION OF CHART SCALE	PER CENT DIFFERENCE
FOXBORO RECORDING THERMOMETER	15 SECONDS	100%
RECORDING THERMOMETER A	32 SECONDS	47%
RECORDING THERMOMETER B	42 SECONDS	37%
RECORDING THERMOMETER C	33 SECONDS	45%
RECORDING THERMOMETER D	85 SECONDS	18%



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Improving Brake Drums and Linings through the Use of Instruments

By CHRIS BOCKIUS and J. HAROLD HUNT
Raybestos-Manhattan, Inc. Motor Wheel Corporation

INCREASED HIGHWAY TRAFFIC and the higher speeds of today are demanding better brake performance. Lowering the center of gravity, and efforts to produce better riding, have brought the smaller wheel into general use and have limited the diameter of brakes, particularly on the larger cars. With the streamlining of bodies, the entire brake assembly is being housed to such an extent that heat is becoming a serious problem. All of these factors combine to make the retarding of a motor vehicle one of the major engineering problems of today. Brake design and structures of the component parts have received concerted attention, not only from the designers of the brakes but from the suppliers of brake drums and brake linings. Both drums and linings play an important part in the problem and a vast amount of research work has been done along this line. Equipment for testing brake lining and brake drums may be divided between laboratory machines and road-test cars. Laboratory machines for testing brake lining have been varied in design. The tendency has been to eliminate any test equipment which does not use the full brake assembly. Manually operated machines are being superseded by full-automatic controls to eliminate inaccuracies of manual operation, and the two machines described herein are automatic dynamometers of this type.

MATERIALS AND TYPES

At present, the following types of drums are in use: (*a*) stamped—both low and high carbon; (*b*) steel ring fastened to a light-steel back; (*c*) full cast iron of various compositions; (*d*) steel and cast-iron ring fastened to a light-steel back; and (*e*) cast-iron ring with back of light steel, cast-in.

Brake-lining types may be classified as follows: (*a*) molded pulp, (*b*) impregnated asbestos-sheet, (*c*) folded and compressed, and (*d*) woven.

(*a*) Molded-pulp linings consist essentially of short-fiber asbestos, combined with inert pigments, and bonded with rubber, synthetic resins, drying oils, or combinations of these binders. The mass is usually hot-pressed hydraulically to form the lining. It is furnished in flexible strips or rigid segments.

(*b*) Impregnated asbestos-sheet consists principally of pure asbestos-sheet impregnated with a suitable binder, formed and heat treated. It is furnished in rigid segments.

(*c*) Folded and compressed linings consist of woven-asbestos cloth, impregnated with a compound of rubber and inert pigments, plied together in strips to give the required width and thickness, then hydraulically compressed and vulcanized. This lining is generally furnished in rolls, but can also be formed in semi-rigid segments.

(*d*) Woven linings. At present, there are several variations of the woven types of lining. The simplest form consists of asbestos yarn woven into a tape and saturated after weaving, rolled to size, and heat treated. It is furnished in rolls. Later types are made with asbestos yarns in which pigments are incorporated together with suitable binders. Some of these types are in the flexible state and are furnished in rolls; others are finished as dense semi-rigid segments.

THE RAYBESTOS-MANHATTAN DYNAMOMETER

The Raybestos-Manhattan Dynamometer was designed for the particular purpose of testing *brake linings* and is, therefore, equipped with special means for mounting the drums and backing-plate assemblies carrying the brake shoes and operating mechanism. The machine is of the inertia-weight type. At the time of the brake application, the flywheel is rotating without driving force, and the energy absorbed by the brake is the kinetic energy stored in the flywheel.

The flywheel has a variable speed range of 205 to 820 r.p.m., approximating car speeds of 18 to 73 m.p.h. based on a 30-in. tire diameter. The flywheel consists of a webbed steel casting and forty-four ¼-in. steel disks, the diameter being 42″. The casting weighs approximately 600 lbs. and each disk weighs approximately 112 lbs. The kinetic energy developed can be varied from 8120 ft-lbs. to 133,500 ft-lbs. from the lowest to the highest speeds, with the flywheel casting only. With additional flywheel disks, the kinetic energy can be varied from 59,500 ft-lbs. to 980,000 ft-lbs. from the lowest to the highest speeds. These ranges in kinetic energy would compare to one-fourth of the kinetic energy developed by vehicles ranging in weight from 3000 to 22,000 lbs.

Figs. 1 and 2 show the dynamometer with its operating and control tables. The following description explains the mechanism and instruments, and their application:

The main motor is started or stopped by a snap switch (1) and then the proper speed is set by means of a vernier rheostat (2). Dial (3) is set for the proper time-stop cycle. Dial (4) is adjusted to set in operation at any desired brake stop the three Bristol recording-strip charts (5-6-7). These charts move at the rate of 12 in. per min. The time-stop cycle is controlled by a set of gears (8) working against electrical contacts (9), the gears being driven by a Telechron motor. The time cycles may be set to operate at 1, 2, 3 or 4-min. intervals. The three Bristol recorders are operated through a set of gears (10) which are geared to the Telechron motor-shaft. The machine runs fully automatic once it is started. If desired to apply the brake at any time other than the set time-cycle, push button (11) is applied manually.

The master cam (12, under case) working on a plunger supplies the hydraulic line pressure to a hydraulic brake or to another hydraulic cylinder to operate a mechanical brake. The speed of the cam (12) is varied by means of a rheostat (13) that controls the speed of the motor (14); but, once the proper speed is determined, it is never changed. The hydraulic-line pressure to the brake is recorded on the Bristol recorder (5) and the Ashcroft-Hancock hydraulic gage (15). The torque output of the brake is recorded on the Bristol recorder (7) and the Ashcroft-Hancock gage (16) by means of the hydraulic cylinder (17) located at the end of the torque arm (18).

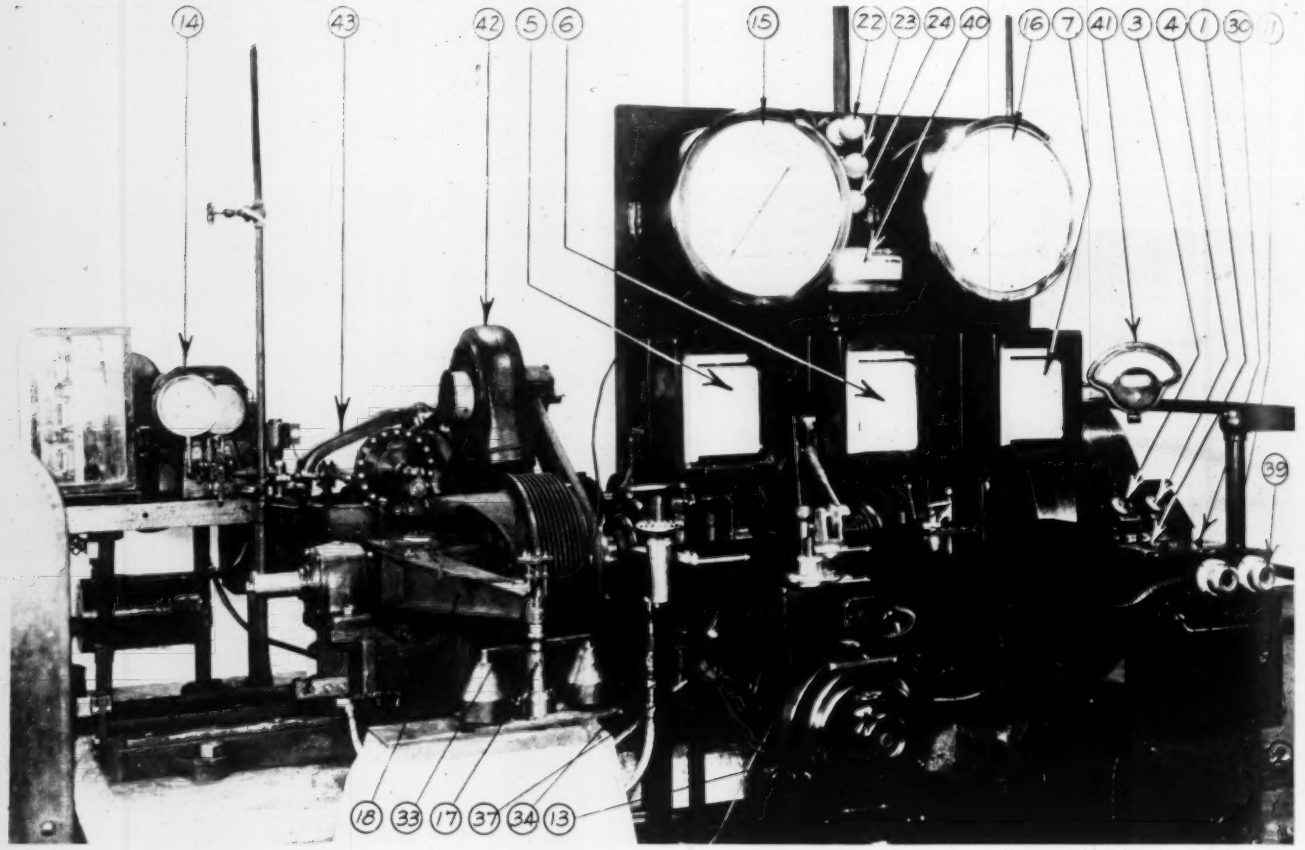


Fig. 1. Front View of the Raybestos-Manhattan Dynamometer, showing Instrument Board

(1) Switch for starting main motor
(2) Vernier rheostat for controlling the speed of the main motor
(3) Time-stop-cycle dial
(4) Dial for setting Bristol recorders to operate at any desired brake-stop.
(5) Input to the brake; Bristol pressure-recording instrument
(6) Revolutions of the flywheel to stop; Bristol instrument
(7) Output of the brake; Bristol pressure-recording instrument
(8) Time-stop-cycle gears
(9) Electrical contacts for (8)
(10) Gears for operating the electrical contacts to operate (5), (6) and (7)
(11) Push button to start the mechanism to apply the brake
(12) Master cam which applies hydraulic-line pressure; under a cover
(13) Rheostat: control speed of (14)
(14) Motor that drives the master cam
(15) Hydraulic gage, indicating the input to the brake
(16) Hydraulic gage, indicating the output of the brake.
(17) Hydraulic cylinder which produces output torque of the brake
(18) Brake torque-arm
(19) Weights for increasing the hydraulic-line pressure
(20) Hydraulic cylinder for master cam; under a cover
(21) Hydraulic cylinder for lifting weights (19)
(22), (23), (24) Signal lights

The input to the brake may be varied by applying dead weights (19) which are lifted by means of line pressure from the master-cam cylinder (20, under case) to cylinder (21) which allows the plunger of the cylinder (21) to float between set limits. In order that the travel of the plunger (21) is always within its limits, there is a set of three indicating lights (22-23-24). Thus, when light (24) is lit, it indicates that plunger (21) has no line pressure behind it. When weights (19) are lifted, light (23) shows and stays lit as long as the proper lift is maintained. If the travel is too much, light (23) goes out and light (22) is illuminated, giving a warning signal. The travel is reduced by turning the handle of the compensating cylinder (25). The three lights are controlled by means of a set of three gears with electrical contacts (in box, 26) and operated by means of a lever (27) connected to weights (19).

In order to maintain the proper level of the torque arm (18) which rests on a plunger in a cylinder (17), the location of the plunger may be varied by means of the volume of liquid from the cylinder (28).

Cam-lever arm (29), which varies the hydraulic-line pressure to the brake, is operated to maintain a constant output of the brake when making a "drag test" with a continuous rotation of the flywheel. Cam lever (29) is released before closing switch (30) which energizes solenoid coil (31) thus causing bar (32) to limit the travel of lift-cylinder plunger (21). At the time of closing switch (30), the master cam (20) starts rotating and stops when reaching its high point, with the motor still rotating. It is then possible to obtain any line pressure to the brake to maintain a constant torque output of the brake. Cylinder (25) supplies the liquid to the master cylinder (20) when its volume is too low and when different-sized brake-cylinders are used.

The Bristol recording-strip chart (6) records the revolutions of the flywheel to stop, and operates as follows: As soon as brake torque is developed, the electrical contact (33) at the end of the torque arm (18) energizes the solenoid coils (34) which in turn closes the friction clutch (35) driven by a chain (36) from the flywheel shaft. The friction-clutch (35) shaft is connected by means of a chain to the Bristol recorder (6). The action is practically instantaneous when brake torque is developed. Arm (37) is for setting the gearbox (38) ratio of flywheel shaft to Bristol recorder (6) which is necessary for changes in speed of the flywheel or changes in the torque output of the brake.

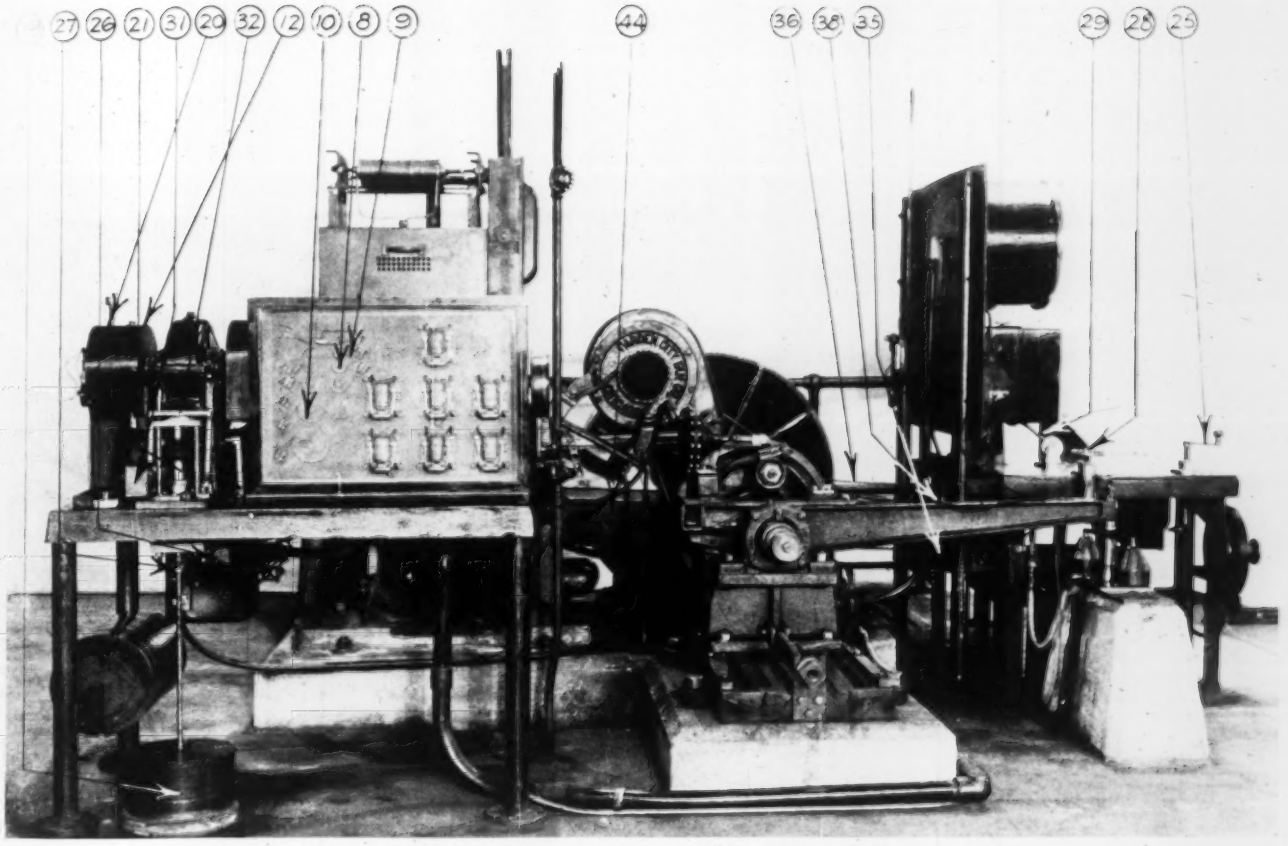


Fig. 2. Side View of Raybestos-Manhattan Dynamometer, showing Operating and Control Tables

(25) Compensating hydraulic cylinder for controlling the volume of liquid to the brake
(26) Gears and electrical contacts controlling lights (22), (23) and (24)
(27) Lever for operating gears (26)
(28) Compensating hydraulic cylinder for setting the height of the torque arm
(29) Cam lever to control the constant torque-output of the brake
(30) Switch to energize solenoid (31)
(31) Solenoid coil to move bar (32)
(32) Bar to lock movement of weights (19)
(33) Contact points to close circuit to solenoid coils (34)
(34) Solenoid coils to close friction clutch (35)
(35) Friction clutch to drive Bristol recorder (6)
(36) Chain to drive the gearbox from the flywheel shaft
(37) Arm for setting different gear ratios
(38) Gearbox for controlling travel of the pen for Bristol instrument (6)
(39) Push button to release the brake
(40) Bristol pyrometer
(41) Weston tachometer
(42) Air-pressure blower to cool the brake drum
(43) Main motor; 30 hp., 115 to 230 volts (D.C.)
(44) Chain connection from the main motor to the flywheel shaft

Push button (30) is used when making a "slow-down" test, thus not allowing the flywheel to come to a dead stop. When the electrical circuit is closed, the cam (12) starts to rotate, releasing the hydraulic-line pressure to the brake and allowing the flywheel to pick up to set speed.

Instrument (40) is a Bristol pyrometer which indicates brake-lining temperature. Instrument (41) is a tachometer, reading in revolutions per minute of the flywheel. The magneto for the tachometer is coupled to the main-motor armature-shaft. The air-pressure blower (42) is belted to the flywheel shaft and cools the brake drum. The main motor (43) is a 30 hp., 115 to 230-volt direct-current machine, chain connected (44, in case) to the flywheel shaft. The motor speed is 2.44 times as fast as that of the flywheel. A portable brake-drum turning-lathe may be inserted on the main base to turn the brake-drum surface concentric with the backing-plate assembly.

The mechanism is available to accommodate hydraulic, cable or lever-operated mechanical-brakes, or air-operated brakes. The illustrations show an air-operated truck-brake assembled for test.

Operation During a Complete Brake-Test Cycle.—Set dial (3) for the desired time cycle; snap switch (1) to start the main motor; set vernier rheostat (2) for the desired flywheel speed; set dial (4) for the desired period to operate Bristol recorders (5-6-7); and snap the switch which is next to switch (1) to start the Telechron time-cycle motor.

When the selected contact, for example (9), is closed, it operates the interlocking relay[1], which engages the friction clutch that operates through a $\frac{3}{4}$-hp. motor (14) armature-shaft, being actuated by solenoid coils, thus driving a reduction unit of 244 to 1 ratio. The slow-speed shaft of the reduction unit carries an insulated revolving disc and shoes which progressively open a series of contacts mounted on a stationary member. Contact No. 1 interlocks the time-cycle relay. Contact No. 2 (operated by a separate insulated shoe, while all other contacts are operated by a shorter shoe) opens the circuit to the main motor. Contact No. 3, through a relay, starts the three Bristol recorder strip charts to move at the selected cycle period. Contact No. 4 stops the reduction unit when the master cam (20), which is mounted on the slow-speed shaft of the reduction unit, is at its highest

[1]To limit over-travel of the high-speed shaft of the reduction unit, a magnetic friction brake is applied the moment the friction clutch is released. The brake is operated through the back contacts of the interlocking relay.

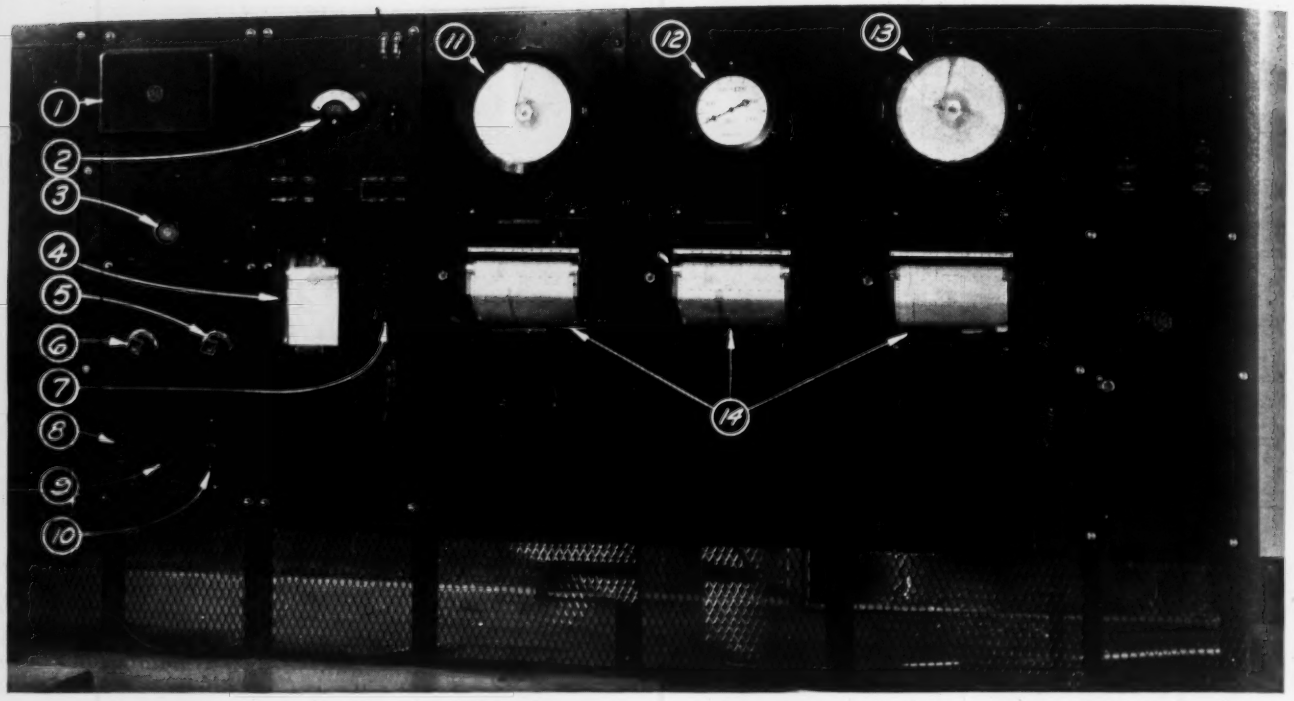


Fig. 3. Instrument Board of the Motor Wheel Corporation's Dynamometer

(1) Stop-interval control-mechanism
(2) Weston indicating tachometer
(3) Pedal effect rheostat. (Controls thrustor pressure.)
(4) Esterline-Angus recording tachometer
(5) Stop interval selector. (Selects for stop every 1, 2 or 3 minutes.)
(6) Motor speed selector. (Four speeds.)
(7) High-speed chart control.
(8) Manual or automatic operation selector
(9) Pedal effort manual switch
(10) Motor control button
(11) Pedal effort recorder
(12) Brake line pressure for hydraulic brakes
(13) Torque recorder
(14) Brown recording pyrometers
(15) Torque-absorbing unit; hydraulic, Motor Wheel design
(16) Torque arm
(17) Brake-application counter

point, thus holding the set hydraulic-line pressure to the brake until the flywheel stops. Then contacts (33) open and, by means of a relay, the reduction unit starts to rotate, thus bringing the master cam to its low point and relieving the line pressure from the brake. During this rotation of the reduction unit, contact No. 5 stops the Bristol recorders; contact No. 2 closes (coming in ahead of contact No. 1 due to the length of the shoe) thus starting the main motor to set speed; then contact No. 1 opens, breaking the interlock of the time-cycle relay until the next cycle.

Raybestos-Manhattan, Inc., has in progress of construction two more similar machines, but which have improvements and higher flywheel speeds. For example, instead of a fixed-automatic time-stop cycle of 1, 2, 3 and 4 min. intervals as already mentioned, the new machines will have an automatic-time-stop-cycle clock, varying from the shortest possible operating time between stops to a maximum interval of 10 min.

THE MOTOR WHEEL CORP. DYNAMOMETER

The Motor Wheel Corp. Dynamometer was designed for the particular purpose of testing *brake drums* and accompanying parts and is, therefore, equipped with special means for mounting the drums and the backing-plate assemblies carrying the brake shoes and operating mechanism. The machine is of the inertia-weight type. At the time of the brake application the flywheel is rotating without driving force and the energy absorbed is the kinetic energy stored therein. The flywheel has four rotating speeds: 354, 476, 718 and 956 r.p.m., approximating car speeds of 30, 40, 60 and 80 m.p.h. The kinetic-energy load can be varied from 22,703 ft-lbs. to 710,103 ft-lbs. This represents a car weighing from approximately 3000 to 13,000 lbs. The mechanism mounted on the tail pillow-block is to apply the brake and absorb the resulting torque. The power to apply the brake is furnished by a General Electric Co. Thrustor. Mechanisms are available so that hydraulic, cable or lever-operated brakes can be accommodated. We can best explain the mechanism, instruments and their uses, by referring to Figs. 3 and 4, of the switchboard and dynamometer.

The motor is started or stopped by means of push button (10) after the proper speed (6) and stop interval (5) have been selected. The stop interval is controlled by mechanism in box (1) and can be selected by (5) so as to stop once in 1 min., once in 2 min. or once in 3 min. The machine runs fully automatic after being started. If it is desired to operate it manually, switch (8) can be set accordingly. Switch (9) operates the thrustor (19) on the dynamometer non-automatically.

Instrument (2) is a speed indicator reading in number of revolutions per minute. Instrument (4) is an Esterline speed recorder with fast and slow paper-feed. A speed-time chart of a stop can be drawn with a paper feed of ¾ in. per sec., giving a good open chart from which decelerations can be accurately determined. Trip (7) operates the fast paper-feed. Instruments (2) and (4) get their energy from tachometer magneto (31) which drives directly from the flywheel shaft. Instrument (11) is a low-pressure recording pressure-gage. This records pedal effort. Instrument (12) is an indicating pressure-gage. Instrument (13) is a high-pressure recording pressure-gage. These two instruments can be used selectively and interchangeably and are used to record or indicate either hydraulic brake-line pressure

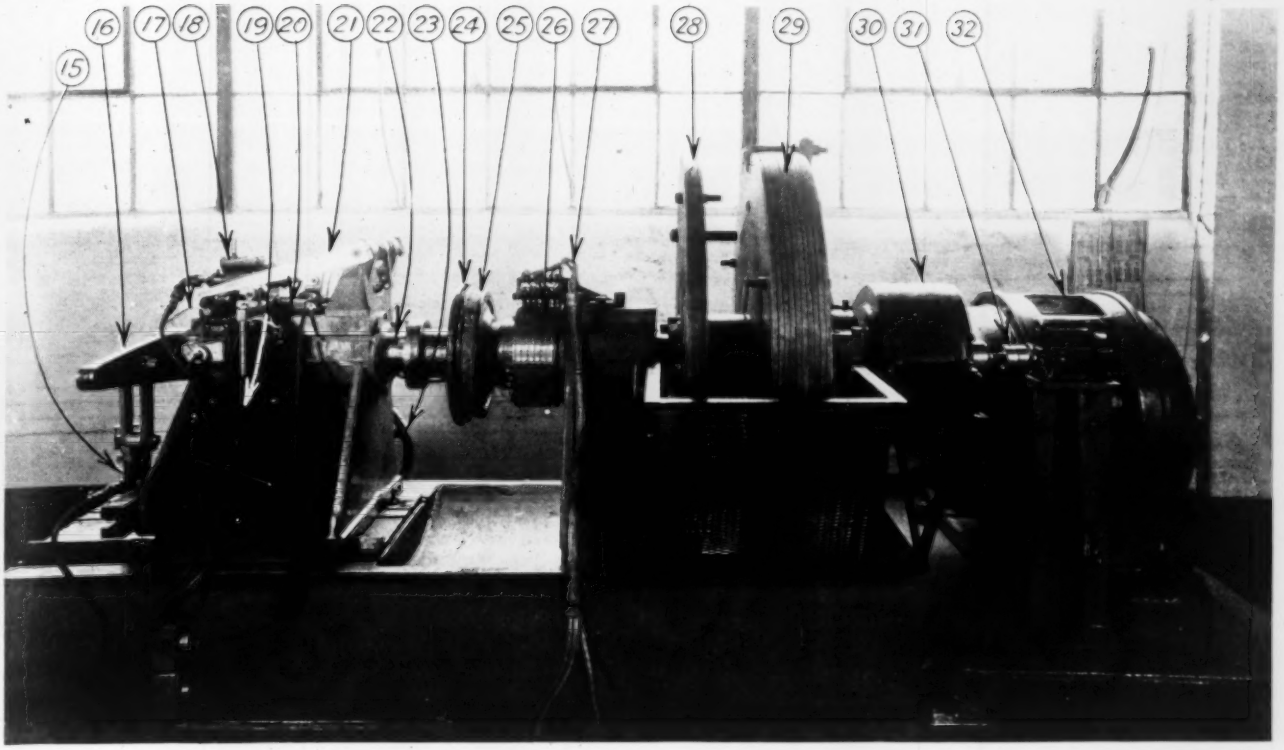


Fig. 4. Side View of the Motor Wheel Corporation's Dynamometer

(18) Hydraulic master-cylinder; gage on the switchboard
(19) Pedal-effect mechanism; General Electric Co. Thrustor
(20) Electric relay for starting; it interlocks to prevent starting with the brake on
(21) Brake-applying levers
(22) Torque shaft
(23) Hand wheel for moving the pillow-block assembly
(24) Backing plate, carrying brake shoes
(25) Brake drum being tested
(26) Pyrometer collector-ring and brushes; temperatures recorded
(27) Pyrometer leads
(28) Active flywheel weights; may be varied from light passenger-car to bus requirements
(29) Idle flywheel weights
(30) Chain and chain case
(31) Tachometer magneto
(32) Fifty-hp., a.c. motor; four speeds

from master cylinder (18) or the torque-absorbing unit (15). Instruments (14) are recording pyrometer potentiometers and record temperatures generated in brake drums and linings. These meters are connected to the pyrometer couples through the collector rings and brushes (26) and the leads (27). Temperatures at three locations can be recorded simultaneously and continuously.

Hand wheel (3) controls the effort of the thrustor (19) which furnishes the pedal effort. The eleven flywheel weights (29) can be moved from active to idle position as the required load may require. The motive power is a 50-hp., 440-volt, A.C. motor (32) chain connected ((30) is chain case) to the flywheel shaft. The motor runs 1.28 times as fast as the flywheel. There is no starting resistance, the switches closing directly across the line.

We have a fixture to mount on this machine that will enable us to record graphically the deflections of a brake drum under brake stresses. The machine set up as shown carries the drum directly on the flywheel shaft; but, by the use of simple arbors a complete wheel, hub and drum assembly can be mounted. The machine will accommodate a tire diameter up to 40 in.

This machine allows us to study the various kinds of a brake drum for: (*a*) Brake-drum performance and characteristics when stopping under varying loads and pressures; (*b*) brake-lining performance and characteristics; (*c*) brake-drum and lining wear; (*d*) heat quantity, location, effect and flow; and (*e*) brake-drum deformations under braking loads, pressures and heat.

In the design of the foregoing machines, the Johns-Manville Corp. contributed the fundamental design of flywheel shaft, base, and main bearings. The other mechanical parts of the machine were designed and calibrated by D. J. Bonawit, and the operating control mechanisms were designed by Judson A. Cook, both of The Manhattan Rubber Mfg. Division of Raybestos-Manhattan, Inc. The Motor Wheel Corporation's machine was designed by its engineering department after conferences and utilizing data obtained from the foregoing companies. It was made to suit their requirements.

LABORATORY TESTS

In general, it should be stated that numerous methods of laboratory testing of brake lining have been in vogue, mainly consisting of testing small sections of the lining. It can be said that all of these methods had some merit, and each contributed its part in the development of the present methods. However, the principal difficulty encountered with such test methods was the difficulty in interpreting test results in terms of car performance. In attempting to arrive at suitable laboratory test methods, it was found that the test equipment must incorporate all the essential parts of any particular brake mechanism in order to correlate laboratory tests and road-car tests. The tests employed by both companies are laid out to parallel actual road testing. The methods of test are still relatively new and subject to change as the technique is developed. The present state of operation may be compared to the first attempts to use dynamometers to test internal-combustion engines, where it was necessary to develop the technique of test before the results were given much credence. Before these machines were employed for test purposes they were carefully calibrated by means of a prony brake.

When installing the brake mechanism in the test machine, it has been found necessary to indicate the drum after it has been mounted on the flywheel shaft to insure perfect concentricity with the brake assembly. The brake lining is mounted on the shoes and prepared according to the brake or the car manufacturer's specifications.

Brake Lining Tests

The following types of brake-lining tests are made on the Raybestos-Manhattan dynamometer: (1) Performance, (2) drag, (3) fade, and (4) pressure-deceleration. These are described as follows:

(1) *Performance.*—The flywheel speed is set to represent a given car-speed in miles per hour. The input to the brake is held constant, or varied so as to obtain a constant torque-output of the brake which is automatically recorded. The brake is applied automatically at a 1, 2, 3, or 4-min. time-cycle. The time to stop and the number of revolutions to stop of the flywheel are automatically recorded, which is interpolated to rate of deceleration in feet per second per second.

(2) *Drag.*—The flywheel is rotated continuously to represent a given car-speed in miles per hour. The input to the brake or the output of the brake can be varied or held constant. When the output of the brake is held constant, it is done manually as previously described.

(3) *Fade.*—The flywheel speed is set to represent a given car-speed in miles per hour. One or more trial stops are made with a cool brake drum so as to obtain a known input to the brake to get a desired output of the brake in feet per second per second deceleration. When this is obtained, then every brake application is made with a constant input, recording the variable output. The brake is applied every 45 sec. or less, depending upon requirements.

(4) *Pressure-Deceleration.*—The flywheel speed is set to represent a given car-speed in miles per hour. The lowest input at which the brake is effective is used at the start of the test, and the input is then increased on each successive stop in equal increments. The operation of the brake is automatic, but the operator must apply dead weights to a lift cylinder to obtain each increase in the input. The time to stop and number of revolutions to stop are recorded. The time cycle is set at 3 or 4-min. intervals to allow the drum to be reasonably cool between stops. The operating system of input to the brake is hydraulic (except for air brakes), and the output of all brakes is hydraulic.

The controls of this dynamometer are sufficiently flexible to permit many variations of the several conventional tests already mentioned. It is possible to control accurately and record the results of all brake tests; that is:

(*a*) Control of input to the brake is accurate and graphically recorded

(*b*) Control of speed is accurate

(*c*) Torque output of the brake is graphically recorded for each stop

(*d*) Variations in deceleration from any speed and time to stop are graphically recorded

(*e*) Temperatures are recorded

(*f*) Energy absorption of any type of brake can be made equivalent to the corresponding vehicle

(*g*) Road surface, tires, weather conditions, the human element, and other variable factors are eliminated

Brake Drum Tests

Motor Wheel Corporation's tests were developed to show the *drum* condition and not brake or lining characteristics. Dynamometer load, brake and lining are determined either by what the customer uses or by the purpose for which we are designing the drum.

Procedure for Running a Deceleration Curve.—The dynamometer is set to operate at a speed equivalent to 30 m.p.h., the interval between stops to be determined by the time required to bring the temperature of the drum back to 100° F., which temperature is used for the start of each stop. Four stops are made at each of the following decelerations: 5, 10, 15 and 20 ft. per sec. per sec. A record is made of line pressure or cable pull, stopping time, torque and drum temperature.

Cooling.—Two couples are used in each drum, one in the center of the ring 0.050 in. from the braking surface and the other in the back, ½ in. from the braking surface and between welds, rivets, or whatever means is used to fasten the back to the drum ring. The couple in the drum ring is connected to a Hoskins instrument, and readings are taken every 30 sec. These readings are also recorded on a Brown instrument for check. The couple in the drum back is recorded on another Brown instrument. The third couple is placed in the air space inside of the brake assembly, and the temperature is checked at this point.

The drum is heated up slowly by dragging the brakes at 30 m.p.h., care being taken to give the assembly time to absorb the heat evenly in order to get as uniform results as possible. When the temperature in the ring reaches 600° F., the brakes are released and the speed is changed to 60 m.p.h. for cooling. Temperature readings are taken every 30 sec., starting at 500° and continuing until 200° is registered. The time elapsed between these two temperatures is the cooling time for this particular drum. To approximate road conditions, a fan is used to direct a light blast of air over the brake assembly during this test, and the temperature of this air is also recorded.

Distortion.—Deflection readings are taken at the open end ¼″ from the face of the drum; at the closed end ¼″ from the back flange; midway between these two points; and on the back ¼″ from the braking surface. Circumferentially around the outside diameter of the drum, readings are taken at the anchor and opposite the anchor; also, at the points where the toe, center and heel of each shoe contacts with the drum.

On these tests, machine speeds equivalent to 40, 60 and 80 m.p.h. are used. At each of these speeds stops are made at a deceleration of 10, 15 and 20 ft./sec./sec. for stopping time.

Fade and Recovery.—The drum is brought to room temperature and ten stops are made from 60 m.p.h. at 1-min. intervals at 15 ft./sec./sec. deceleration. The speed is then changed to 40 m.p.h. and the time interval to 2 min. and ten more stops are made to determine where recovery takes place. Readings of temperature, line pressure or cable pull, stopping time and torque are taken for each stop.

Destruction.—The dynamometer is operated at 40 m.p.h. until the lining shows about 75% contact. A stopping time of 8 sec. is used at the start of this period, and this is gradually decreased to 4 sec. One hundred stops are then made from 60 m.p.h. at 2-min. intervals with a stopping time of 6 sec. Speed is then increased to 80 m.p.h. and the following stops are made at 3-min. intervals: 25 each at 8 sec., at 6 sec., at 5 sec., and at 4 sec.

If the drum is still in satisfactory condition, the load is increased by adding one disk to the flywheel and repeating the 80-m.p.h. stops.

Special Forms of Cathode-ray Tubes

Fourteenth part of "The Cathode-ray Oscillograph and Its Applications" being published serially in *Instruments*. This series began in the July 1935 issue.

By RALPH R. BATCHER

Radio engineer; cathode-ray and electronic application specialist, Hollis, L. I., N. Y.

The tubes described heretofore were all designed primarily for oscillographic purposes and are provided with luminous screens and other requisites of oscillography. Cathode-ray tubes, however, are used for other purposes. For example, the current-carrying properties of a cathode ray can be utilized in order to make a cathode-ray tube serve as a relay, oscillator or amplifier. In these applications a distinction is made between such tubes and the ordinary electron tubes (diodes, triodes, etc.) by defining a cathode-ray tube as one utilizing an electron stream that can be deflected or directed at will by the application of suitable deflection fields.

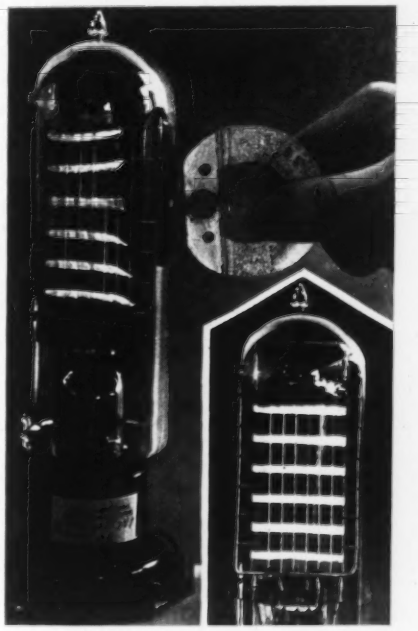


Fig. 1

This distinction is subject to further defining, however, as there are a number of border-line tubes which utilize directed streams of electrons for purely amplification purposes, as for example the recent "beam" amplifier tubes, such as the 6L6. In such tubes the electrons are confined to portions of the tube structure which can be physically held to extremely close tolerances, such being necessary for optimum results.

Another interesting border-line tube is the Type 787 demonstration tube recently developed by Westinghouse (Fig. 1) in which the electron paths between the cathode and the anode through the grid mesh are visibly outlined on the fluorescent coating of the anode.[1] The effect of externally applied magnetic fields, for example, is clearly visible. Such tubes are mainly useful in lecture-room instruction.

Another class of tubes which more nearly comes within commonly-accepted definitions of cathode-ray types is the Type 6E5 (and similar styles). The 6E5, Fig. 2, is essentially a voltage indicator, with the "pointer and scale" in the form of a fluorescent sector visible on a circular target, the angular shadow limits depending upon the potential applied to the control grid.[2] The voltage limit is not large, a matter of about 8 volts being sufficient to change the shadow angle a little over 100 degrees—its whole range. The angular change is not linear (see Fig. 3) so that the tube is mainly useful for indicating changes and trends rather than for exact measurements.

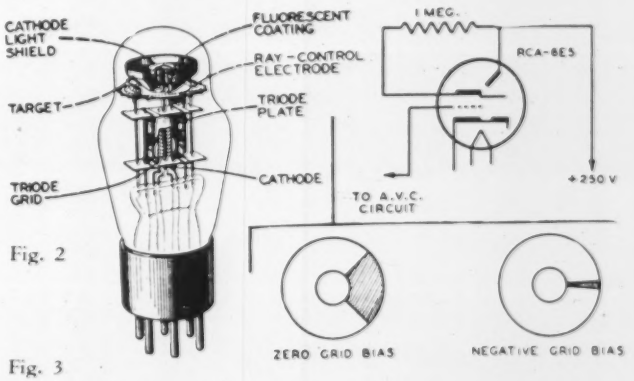
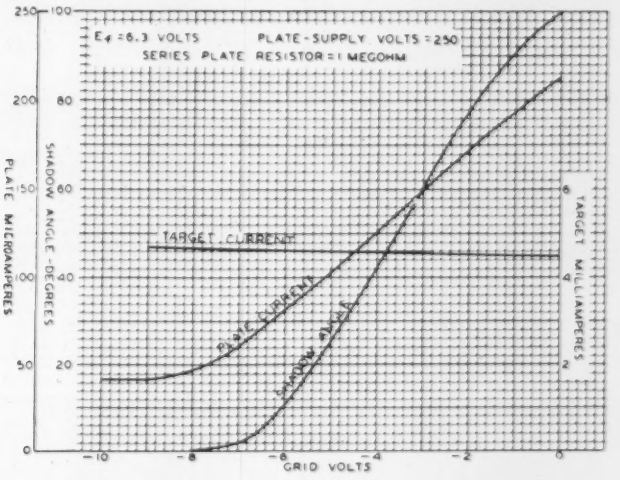


Fig. 2

Fig. 3



The tube operates between two rather definite input limits, from zero to eight volts negative on the control element. The actual range can be increased by biasing the tube a definite and controllable amount below cutoff, so that the tube will function only when the input is sufficient to counteract this bias.

This application of cathode-ray tubes as "limit indicators" will be described in further detail in later articles dealing with certain industrial applications.

DEFLECTION CONTROLLED OSCILLATORS

One of the earliest applications of a cathode ray to non-oscillographic purposes was the cathode ray switch designed by Vreeland in 1906; an oscillator, as in Fig. 4,

[1] Anon. Vacuum Triode with Fluorescent Plate. *Instruments*, Vol. 9, July 1936, page 176.

[2] Ulrey. New Electronic Tubes and New Uses. *Physics*, Vol. 7, March 1936, pages 97-105.

for generating audio frequency potentials. A cathode-ray stream, capable of carrying relatively large currents is generated in a bulb T by the cathode which takes the form of a pool of mercury. This stream is deflected back and forth between anodes A_1 and A_2 by two deflection coils, L_1 and L_2. These coils are polarized so that if the

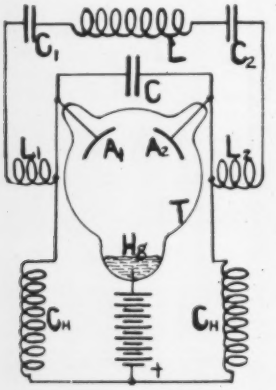


Fig. 4

ray strikes either anode, the field deflects the ray over to the other one. This back-and-forth movement is stabilized by the tuned circuit L_1-C_1-L-C_2-L_2-C as shown. The choke coils in the leads to the anodes are necessary parts of the circuit, limiting the current in the tube, and introducing voltage surges at critical moments. This action is regenerative, and sustained oscillations are obtainable with relatively large power output.

FREQUENCY MULTIPLIERS

Other investigators have extended this general principle to the generation of multi-phase oscillations, and to frequency multiplication, but many of their schemes do not use the regeneration principle but require the application of a control frequency from an external source.

As an example, Hough discloses[3] a generator for three (or more) phase currents using a cathode-ray tube. Here the control frequency is applied to a rotator circuit (see April article) so as to direct the ray along a circular path on the screen. The ray successively strikes three targets located at the end of the tube. The current pulses collected by these targets feed through three similar vacuum tube amplifiers into a three-phase transformer, and thence to a three-phase load as required.

Another application, by Hund, is a frequency multiplier.[4] This principle is not unlike the above except that a single target is used with a plurality of arms, *i.e.*, a multi pointed star. As the ray falls on the various arms of this target, as it passes along its circular path, it creates a series of pulses which are suitably amplified. The frequency multiplication factor is therefore exactly equal to the number of arms on the target.

Several applications of similar principles have been shown by Marrison.[5] In one form, two identical targets are used each having a number of radial arms or spokes, somewhat like those described by Hund. These targets are located in parallel planes coaxially with the tube. The spokes of these targets alternate so that the ray falls alternately on one target and then on the other. The pulses due to the charge deposited by the ray are fed to the two input leads of a push-pull amplifier and thus a frequency is produced that is an exact multiple of the frequency applied to the rotator circuit.

[3]Hough. Means for Generating Three-phase Currents. U. S. Patent No. 1763309.
[4]Hund. Frequency Multiplier. U. S. Patent No. 1929067.
[5]Marrison. Frequency Production. U. S. Patents No. 1882849 and 1882850.

This principle has been extended by Marrison to other uses, such as the determination of phase difference, and as an indicator or alarm when two independent frequencies (one being a harmonic of the other) get out of phase. A star-shaped metal target is used here also, with the number of arms on the star equivalent to the order of the harmonic. The fundamental frequency is used to rotate the spot along a circular path, while the upper frequency is applied to the anode circuit, so that it alternately increases and decreases the anode potential. This changes the sensitivity of the deflection system, so that a star-shaped figure results, having the same number of points as the target. The size of the figure is adjusted so that the figure follows the contour of, but just misses hitting the target. If the phase difference between the two frequencies changes by a small amount, however, the ray will hit the target and manifest itself on an amplifier.

Heintz[6] has extended this process by incorporating a modulating arrangement in a multiphase generating circuit which is somewhat similar in principle to those above. Three-phase currents are obtained by the use of three spoked targets (coaxially arranged) with the spokes alternating, so that the rotating spot hits them successively. A coaxial solenoid around the tube is fed by a direct potential of a value sufficient to focus the spot as required. A voice current amplifier also feeds an alternating potential in series with the fixed potential across this coil and, by altering the focus of the spot, modulates the output power.

ELECTRON RELAYS

Other tubes with metal collectors in addition to, or in lieu of, fluorescent screens, have been used in other ways. One application requires a target inside of the tube, cut out to the shape of the normal figure expected for some specific use. If the conditions change for some reason and a variation in the shape of the oscillogram occurs, an alarm is sounded or a signal is flashed.

Specific examples have been disclosed in several British patents. A patent issued to Watt[7] uses a cathode-ray tube as a radio direction finder, wherein two crossed loops are connected to the pairs of deflection plates. The normal indication is a radial streak of light. By rotating the loops this line can be made to coincide with a narrow metal target placed inside of the tube near the screen and connected to some alarm device. The electrons striking the target produce a current to operate suitable relays. If the direction of the incoming radio wave changes, the line of light will no longer coincide with the target, and the alarm is sounded.

Seymour and Horton[8] have suggested a variation to this device in which the screen is in the form of two strips, or else sectors of circles with a small radial gap between them. The normal movement of the ray in direction-finder work is a line that is adjusted to this gap. For this purpose external deflection plates, that can be rotated around the tube, are suggested. If the direction of the incoming wave changes, the ray will hit one or the other of the targets and will operate some desired type of indicator.

Still another plan[9] uses a circular target from which a small "pie-shaped" sector is cut out, and insulated from the rest of the target. When the incoming wave

[6]Heintz. Frequency Converter. U. S. Patent No. 1983172.
[7]British Patent No. 252263; also The Cathode Ray Oscillograph in Radio Research, by Watson-Watt. His Majesty's Stationery Office, London.
[8]British Patent No. 247344.
[9]British Patent No. 280235.

[illegible] produced a vector change in the potentials, connected to the deflection plates, the ray moves over to the [illegible] target.

These three devices in general vary only as to the shape of the metal targets.

Details of the practicable direction-finder circuits will be described in a subsequent article.

CANAL RAYS[10, 11, 12]

Although positive ions are not of primary interest in a simple study of cathode rays, still they have considerable effect upon the operation of the tube. The passage of cathode rays through a rarefied gas produces ionization by impact with the gas molecules. The positive ions created in this way are attracted by the cathode and by any other negatively charged electrodes.

This action furnishes a clue to the peculiar effect of the broken glow column observed in early Crookes and Geissler tubes. After the negative electron leaves the cathode it rapidly increases in velocity. Until it reaches

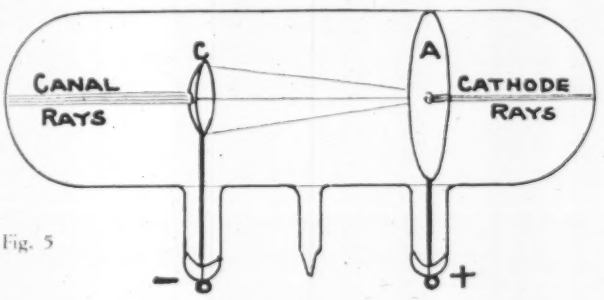


Fig. 5

a certain velocity, however, it is incapable of causing ionization by impact with molecules. Thus a certain space interval is found between the cathode and the region of glow. The ionized particles created have a positive charge and travel back toward the cathode. After gaining a certain speed these ions are also capable of causing additional ionization; thereby producing the region of glow that surrounds the cathode. If the cathode has one or more openings in it, some of these ions will pass through to the end of the tube.

These positive rays passing *back* from the cathode are generally known as canal rays. Fig. 5 is a sketch of a tube that shows these effects. The canal rays are made visible by the fluorescence of the gas or the glass in partially evacuated tubes, and are usually an orange-red color.

Canal rays are also capable of being deflected with a magnet and, having a positive charge, their deflection is opposite to that of cathode rays. Their velocity is very much slower than that of cathode rays and so they are capable of producing only a slight fluorescent action compared with cathode rays.

LENARD RAYS[13, 14]

Nearly fifty years ago Lenard demonstrated the possibility of projecting cathode-ray streams through the envelope of the generating tube. His first experiments used a small window, less than a tenth of an inch in diameter, covered with a metal foil. This tube was operated at high anode potentials (>100 kv.). The percentage of electrons that will pass thickness of window depends upon their velocity. A loss of intensity will be encountered in any case, and upon emergence the ray is quickly absorbed by ionization of the atmosphere, so that their effects must be studied within a few inches of the window. The range in air is approximately proportional to the fourth power of the velocity.

The window must also withstand the pressure of the atmosphere so that if larger windows are used they must be reinforced by a metal grille. Besides, this thin foil is more or less porous so that a vacuum pump must be connected at all times that the tube is in use.

As an example, an aluminum sheet 0.0005″ will pass better than 50% of the ray when a 70 kilovolt anode potential is used. The absorbed energy is partially dissipated as heat, X rays, ionization, etc.

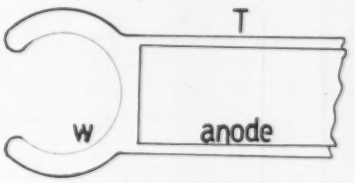


Fig. 6

Fig. 7

Dr. Slack of the Westinghouse Lamp Co., has built Lenard tubes with a glass window about 0.002 mm. thick.[15] This window in its usual form was of the shape shown in Fig. 6 where *W* is a thin concave bubble of glass drawn inward from the end of the tube *T*. This shape protects the fragile glass window. Glass of this thickness will pass the rays about the same as aluminum, and has the advantage that the tube will hold its vacuum and can be sealed off from the pump. Fig. 7 shows the commercial form of this tube, known as Type WL 785. The window of this tube is of such a shape that oscillographic records are difficult to obtain, by reason of impracticability of placing sensitive film next to the window. The glass is so thin that even the slightest mechanical pressure will cause it to shatter.

The anode end of the tube is internally gold plated and the window proper is coated with thin aluminum

[10] Dempster. Properties of Slow Canal Rays. *Physical Review*, Vol. 8, 1916, pages 651-662.

[11] Ewers. Zur Mechanik der Canal und Kathodenstrahlen. *Annalen Der Physik & Chemie*, Vol. 69, 1899, pages 167-200.

[12] Austin. Canal Rays. *Bureau of Standards Journal of Research, Sci. Paper, S23*, 1905.

[13] MacGregor, Morris and Mines. Measurements with the Cathode-ray Oscillograph. *Journal Institute of Electrical Engineers*, Vol. 63, 1925, pages 1056-1096.

[14] Wood. Recent Developments in Cathode-ray Oscillography. *Journal Institute of Electrical Engineers*, Vol. 71, 1932, pages 41-56.

[15] Slack. Lenard Ray Tube with Glass Window. *Journal Optical Society of America*, Vol. 18, 1929, page 123.

foil to reduce the charges which might accumulate at that point.[16,17] Focusing conditions have been predetermined and no external controls are required. A tungsten filament requiring approximately forty watts is used. The normal anode potentials used are from 100 to 250 kilovolts.

A tube described by Coolidge[18,19,20] employed a metal foil window, reinforced by a metallic grid backing. The foil was 0.03 mm. thick but even at this thickness a small amount of air passes through, and a four-stage mercury diffusion pump was permanently connected. Voltages up to 900 kilovolts were used with this type, and an intense beam was obtained.

A number of Lenard tubes[21-28] have been constructed with metal windows for oscillographic purposes. Such tubes may have an advantage for the study of transient surges or lightning, where the high transverse speed of the spot requires direct exposure of the film to the rays, without the intermediate fluorescent screen, for a satisfactory record. Fluorescent screens are at best useful with low-speed rays and fail to respond to higher ray velocities with increased brilliance. The Lenard tube, even with the inconveniences of the continuous evacuation, limited screen area, and the lack of a simultaneous visual monitoring arrangement during the recording interval, probably has a greater operating simplicity than a tube which must be dissassembled each time it is used, and reloaded with new film.

However, the main application for Lenard rays seem to be in the chemical, biological and physical fields,[29,30,31] where many new principles have already been discovered.

A brief outline of a few of these discoveries has been obtained from the Westinghouse Lamp Co. referring to the above-mentioned WL 785 tube. Exposure of plant tissues to Lenard rays has resulted in rather prompt drying up of exposed portions. Bacteria are killed with even short exposures, and fruit flies and other insects are promptly killed. Fluorescent tests and visual investigation in a dark room have shown that the electrons produce an elongated spherical field beyond the end of the window, which has a field of influence up to about 12 inches. All fluorescent materials will glow upon exposure, and calcite produces scintillations.

[16] Taylor, Measurement of Lenard Rays, *Bureau of Standards Journal of Research*, Vol. 5, 1931, pages 57-72.
[17] Dennington, Westinghouse Lenard Tube, *Electronics*, Vol. 1, 1930, pages 294-295.
[18] Coolidge & Moore, Experimental Study of Cathode Rays Outside of Generating Tube, *General Electric Review*, Vol. 35, 1932, pages 413-417.
[19] Coolidge & Moore, Application of High-voltage Cathode Rays, *Journal Franklin Institute*, Vol. 202, 1926, pages 722-735.
[20] Coolidge, The Production of Cathode Rays Outside the Generating Tube, *Journal Franklin Institute*, Vol. 202, 1926, pages 693-721.
[21] Knoll, Aussen aufnahmen von Kathodenstrahlen Oszillographen durch Lenardfenster, *Zeitschritt fur Technische Physik*, Vol. 10, 1929, pages 28-30.
[22] Knoll, Vakuum technische Neuerungen an Kathodenstrahlen Oszillographen, *Zeitschritt fur Technische Physik*, Vol. 10, 1929, pages 294-299.
[23] Knoll & Borries, Aussenphotographie beim Kathodenstrahlen Oszillographie durch grosse Bildfenster, *Zeitschritt fur Technische Physik*, Vol. 11, 1930, pages 111-112.
[24] Knoll & Borries, Aussen aufnahme schneller Kathodenstrahloszillogram durch Lenardfenster, *Zeitschritt fur Technische Physik*, Vol. 11, 1930, pages 495-495.
[25] Matthias, Knoll & Knoblauch, Kathodenstrahloszillograph liegender Bauart, *Zeitschritt fur Technische Physik*, Vol. 11, 1930, pages 276-282.
[26] Knoll, Leuchtschirm Kontakt photographie beim Kathodenstrahlenoszillograph, *Zeitschritt fur Technische Physik*, Vol. 11, 1930, pages 491-493.
[27] Knoll, Recording of Fast Transient Phenomena, *A.I.E.E. Journal*, Vol. 49, 1930, pages 463-465.
[28] Knoll, Oscillograph with Lenard window, *Review of Scientific Instruments*, Vol. 1, 1930, pages 507-511.
[29] Hoskins, Cathode Ray Tube in Biological Service, Lenard Tubes, *General Electric Review*, Vol. 35, 1932, pages 367-370.
[30] Hoskins, Cathode Ray Tube in Biological Service, Lenard Tubes, *General Electric Review*, Vol. 35, 1932, pages 465-471.
[31] McLennan, Perrin & Ireton, Action of High-speed Electrons on Acetylene, *Proceedings of the Royal Society*, Vol. 125, 1929, pages 246-248.

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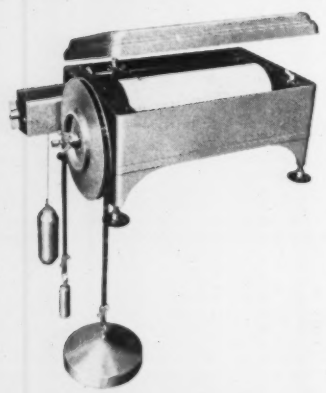

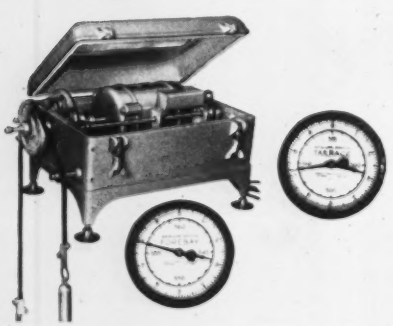

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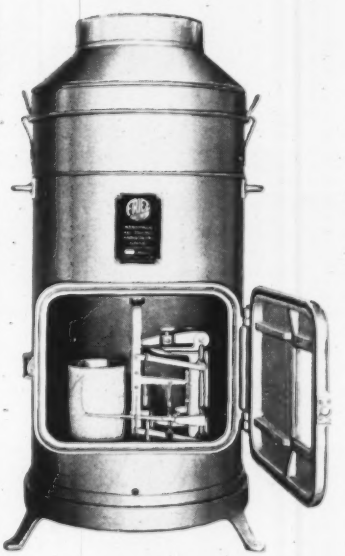

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By PERRY A. BORDEN and M. F. BEHAR
Member A.I.E.E. Editor, *Instruments*

4. The Regulation of A-C. Feeder Voltages.

The ease with which the principle of the transformer may be applied in raising and lowering voltages renders the regulation of individual feeders independently of the generators a thoroughly practical engineering matter. Though a discussion of the induction regulator and the multiple-tap transformer is not within the scope of this work it may not be amiss to outline their general operating principles.[19] The induction regulator is essentially a transformer having a portion of its magnetic circuit movable, so that the pro-

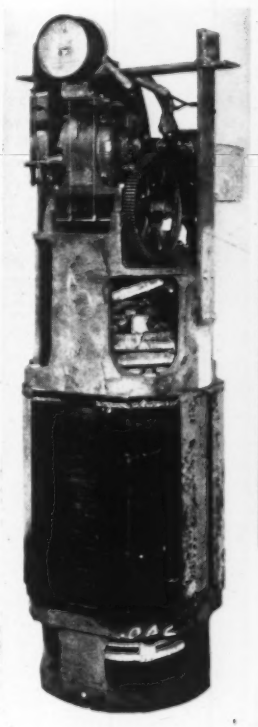

Fig. 48-17a

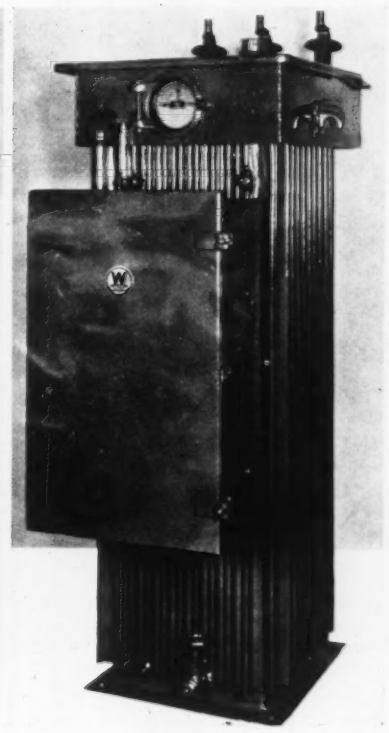

Fig. 48-17b

portion of the primary flux linking with the secondary may be varied through a wide range without materially changing the total impedance of the system. The turn ratio may be in order of 10/1, and the secondary winding carries the whole of the line current. Structurally, the induction regulator resembles an induction motor, and either the primary or the secondary winding may be carried by the rotatable member. Fig. 48-17a shows the general appearance of the interior of a Westinghouse induction regulator, the whole operating in oil in a suitable tank, as shown in Fig. 48-17b. The instrument at the top is a mechanical position indicator operated by cables from the rotor and calibrated in terms of the percent by which the line voltage is raised or lowered.

The theories of operation of single-phase and polyphase regulators differ materially, in that in the former the actual value of the secondary voltage is varied, while in the latter the phase positions of the three secondary voltages

[19] For a complete discussion of induction regulators see G.E. Bulletin 1030.

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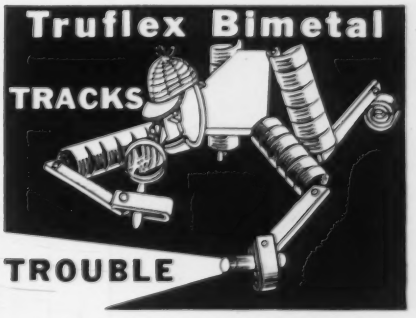

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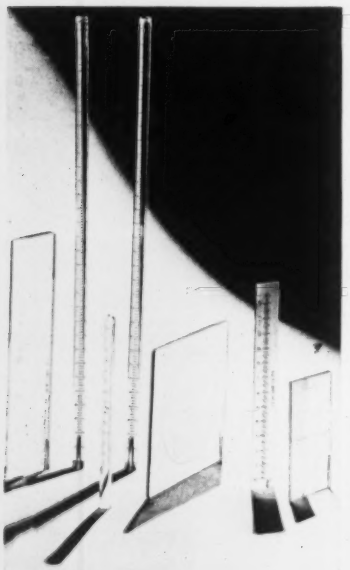

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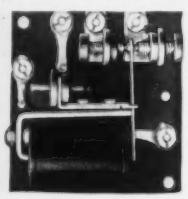
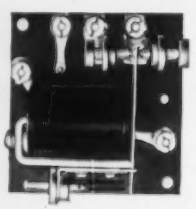


2C



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are changed in relation to the primary voltages. Thus, while for purposes of cutting an induction regulator into or out of circuit, the secondary winding of a single-phase unit may be temporarily short-circuited when the regulated and unregulated voltages are of equal value, this is not possible with a polyphase regulator, and special expedients must be adopted in order to cut such a unit into or out of circuit without a momentary interruption of service.

The multiple-tapped transformer may take any one of a variety of forms, a secondary winding or a portion of the primary winding being provided with taps brought out to contacts on a dial plate or the equivalent, and provision being made for including more or less of the windings in circuit as required. Special provision must be made for changing taps under load, in order that short-circuit currents may not flow at times when two or more contacts are bridged by the traveling contactor or brush. In general, it may be said that there are available transformers through which a voltage may readily be adjusted by rotation of a shaft. Thus, it is possible to control the voltage of an outlying feeder by practically any of the methods applicable to the automatic adjustment of a field rheostat.

Induction regulators are generally supplied as units, each including a primary and a secondary relay. The primary relay, such as Fig. 48-18 (Westinghouse), is in the nature of a contact-making voltmeter having an operating range confined to the zone of regulation, and serving in turn to actuate the secondary relay. The latter is a magnetic contactor giving reversible operation to an induction motor. A "line-drop compensator," supplied as standard equipment with feeder regulators, is an auxiliary network by which a voltage depending upon the value of the line current is caused to act in conjunction with the line voltage in governing the pull on the plunger of the primary relay. As the proportional effect of the line current may be adjusted for current and phase-angle conditions, it is possible to give the regulator any desired degree of over-compounding. As feeder regulators are practically never operated in parallel on their regulated sides, it is not necessary to provide auxiliary devices to govern the sharing of active or reactive volt-amperes.

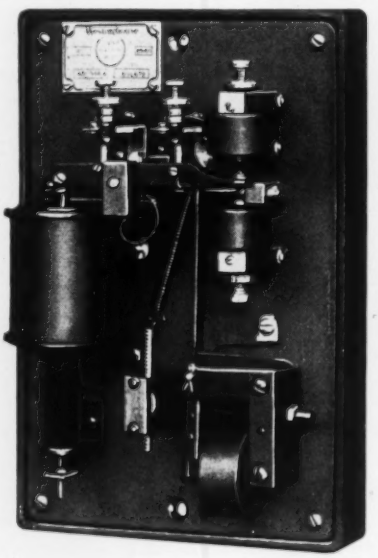

Fig. 48-18

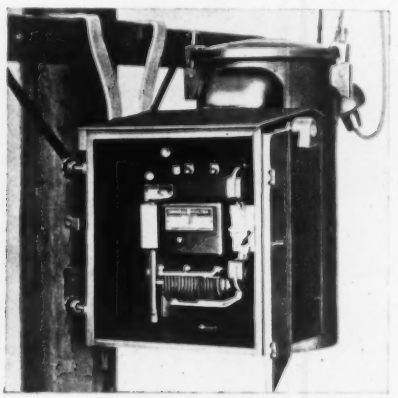

Fig. 48-19

Induction regulators are regularly available in a great variety of ratings from the small pole-mounted unit of a few kilowatts, such as the G-E branch-feeder step-voltage booster shown in Fig. 48-19, to station and outdoor-type units capable of regulating feeders carrying a load of 1,000 kilowatts or more.

5. Regulators with Static Sensitive Elements.

As previously pointed out, the term "static" is here applied to those forms of measuring elements in which mechanical movement does not take place, as contrasted with those forms of elements which are the equivalents of ordinary voltmeters of various types. In the "kinetic" class of elements the tendency is to effect a balance between a force which varies with controlled voltage and another force which is substantially constant in value. In sensitive elements of the static type use is made of other phenomena which vary with electrical conditions. These have already been classified as: Type 3—Saturable magnetic circuits; Type 4—Electron tubes; Type 5—Circuits utilizing non-linear resistances. In the final analysis it may be claimed that practically all the above devices make use of non-linear characteristics; but in this grouping it

been thought desirable to segregate non-linear resistances as having a property which is more or less inherent in saturable reactors and certain electron tubes.

Two or more of these principles are so frequently found combined in modern regulating devices that a complete classification is impracticable; and the systems to be discussed will be grouped according to their primary sensitive elements. It is manifestly impossible in these pages to describe, or even refer to, every sub-type of regulator utilizing these three types of "static" measuring elements.

(a) The Saturable Magnetic Circuit.

The non-linear characteristic of magnetic circuits due to saturation of ferrous materials has been applied in many ways in the regulation of generator potentials and of the voltages and currents derived from a-c. lines supplied from unregulated sources or carrying variable loads. The saturable-cored reactor has been used as a regulator of electric systems since as early in 1901,[11] but it is only within the last decade that its application has become of prime importance. The operating principle is essentially based upon the fact that the self- or mutual-inductance of a reactor system depends upon the permeability of its magnetic circuit, and that the permeability of a certain specimen of iron is definitely related to the flux which it carries.

There may be said to be two general classes of regulators in which the prime response is based on magnetic saturation. One of these, particularly adaptable to small line or feeder regulators, is of the type in which the current flowing is caused to vary the saturation, and hence the permeance, of a part of the core in a transformer device, and thus affect either the total reactance in the electrical circuit or the value of an auxiliary voltage added to, or subtracted from, that of the outgoing feeder.[12-14] In the other type, variations in the regulated voltage are detected, amplified and rectified by means of thermionic tubes or other devices, and the direct current so derived caused to modify the degree of saturation of the core.[15] As either or both of these principles may be combined in a system wherein a derived current is supplied to the field of a generator, the use of the method will be seen to have many ramifications.

Small Feeder Regulators.

The general action of the saturable-cored transformer in line regulation will be understood by reference to Fig. 48-20, which is an elementary diagram of a small regulator built by the Sola Corporation.[16] The portion A of the core functions as a step-up auto transformer; and, when the line voltage falls below a predetermined limit, acts to build up the outgoing voltage to the proper value. The arm C of the core normally operates slightly below the knee of the saturation curve of the iron. As the line voltage rises, the increase in saturation of this part tends to force a greater proportion of the flux through the high reluctance path B, increasing the excitation in a winding which tends to oppose the effect of the main winding, and tending to maintain the voltage at a predetermined value.

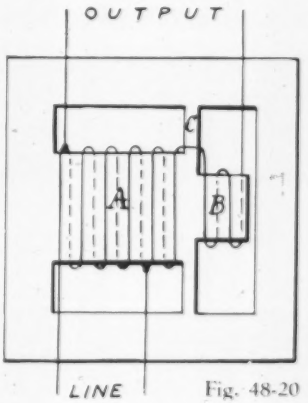

Fig. 48-20

Another form of line regulator utilizing magnetic saturation is exemplified by a Raytheon device[17] available in single-phase units up to a rating of 2 kilowatts. This regulator utilizes two transformers with their respective primaries and their respective secondaries in series. One transformer operates at moderate magnetic density, and the other at a value approaching saturation, the latter being partially resonated by means of a capacitor. The degree of resonance is governed by the saturation of the transformer, introducing into the network a voltage vector varying in value and phase position with changes in the line voltage. The output voltage is made up of two components, one being the potential across the resonant system; and, by proper proportioning of the elements of the network, the change in value and phase relation of these components is caused to result in a substantially constant output voltage over a considerable range of primary variation.

These two regulators represent a considerable variety now available in small sizes, for individual installations such as radio sets, photometric lamps, etc. In

[11] U.S. Patent No. 720,884. Burgess & Frankenfield, Feb. 17, 1903.
[12] U.S. Patent No. 1,828,900. Kouyoumjian, Oct. 27, 1931.
[13] U.S. Patent No. 1,830,232. Kouyoumjian, Nov. 3, 1931.
[14] F. Bedell and J. Kuhn. Voltage-Regulating Auto-transformer. *Review of Scientific Instruments*, Vol. 3, Jan. 1932, pages 20-23.
[15] U.S. Patent No. 2,003,945. F. G. Logan, June 4, 1935.
[16] U.S. Patent 1,854,490. J. G. Sola, April 19, 1932.
[17] U.S. Patent 1,985,634 & 5. W. K. Fleming, Dec. 25, 1934.

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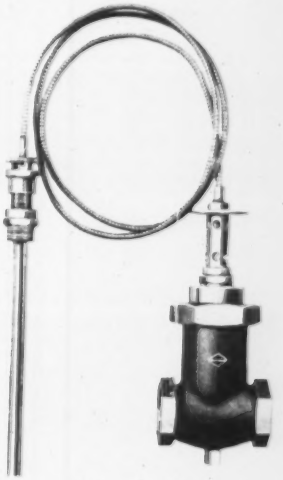

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general they give satisfactory control so far as the effective value of the voltage is concerned; but variations in the frequency of the supply or in the power factor of the load, the relatively great magnetizing current required, and a characteristic distortion of output wave form, limit their use to non-inductive circuits of small power consumption.

Larger "Type 3" Regulators

The saturable-cored reactor has been effectively combined with the rectifier circuit in the recently introduced Westinghouse "Type CR-1," a simple regulator suitable for use on small (<100kva) generator units. It maintains its control of the generator voltage by adding the regulator current output to the exciter field current. This output consists of two components derived from separate full-wave rectifiers, one producing a current proportional to the deviation of the regulated voltage from normal, and the other supplied from a current transformer in the a-c. bus. Fig. 48-21 is a diagram of this regulator[18] so drawn as to bring out its three functional divisions, which are designated as "voltage-measuring unit," "compounding unit" and "voltage-correcting unit." Note however that the saturable-cored reactor (shaded in the diagram) is an essential part of *all three* "units" and that it is in fact not only the "heart" of the regulator but its "brain" as well.

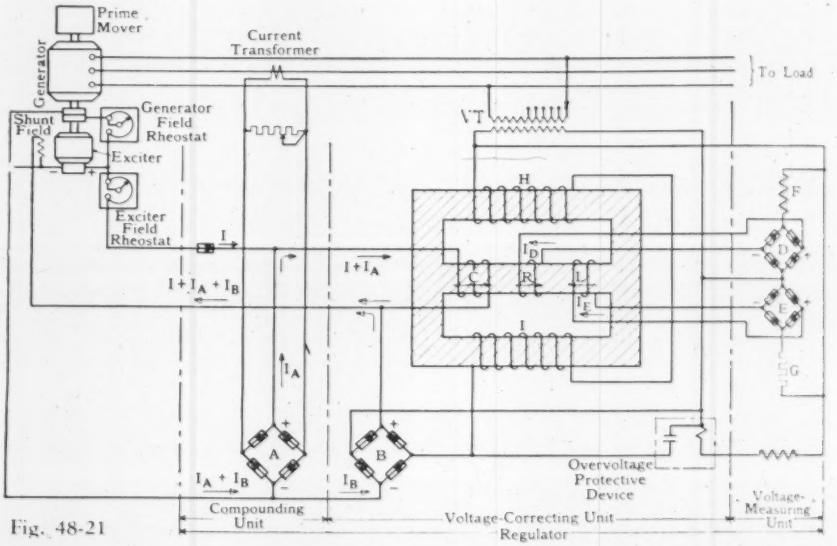

Fig. 48-21

The "voltage-correcting unit" may conveniently be considered first. It consists of the saturable-cored reactor, in series with a full-wave rectifier B. This is energized from the a-c. bus. The exciter field current passes through the coil C, partially saturating the iron, and holding the reactance at an intermediate value when the core is subject to no other magnetizing effect. This represents a stable condition; and normal excitation is obtained from the rectifier B. Compounding is obtained from the full-wave rectifier A, supplied from the current transformer and adding its output to the field current.

The voltage-measuring unit consists of two full-wave rectifiers connected in parallel to the voltage transformer VT, one in series with an iron-cored reactor F and the other through a resistor G. The d-c. outputs of these rectifiers act in opposition in separate windings R and L on the middle core of the reactor. Current in coil L will vary directly as the voltage, while, due to saturation of the iron core in reactor F, the variation of current in coil R will bear a non-linear relation to changes in voltage. Adjustment is made so that the characteristic curves of these networks cross at a value representing the correct voltage. If the bus voltage drops below the set value, current from E will predominate, magnetizing the reactor in the same sense as coil C, increasing the saturation, decreasing the reactor impedance, and permitting more rectified current to flow in the exciter field. If the voltage rises above normal, the output of the saturated reactor F increases more rapidly, and its rectified output flowing in coil R tends to increase the saturation of the main core, thus increasing the impedance and lessening the flow of rectified current in the exciter field.

To be continued

[18] C. P. West & L. D. Applegate, A Generator-voltage Regulator Without Moving Parts, *Electric Journal*, Vol. 33, April 1936, pages 181-183.

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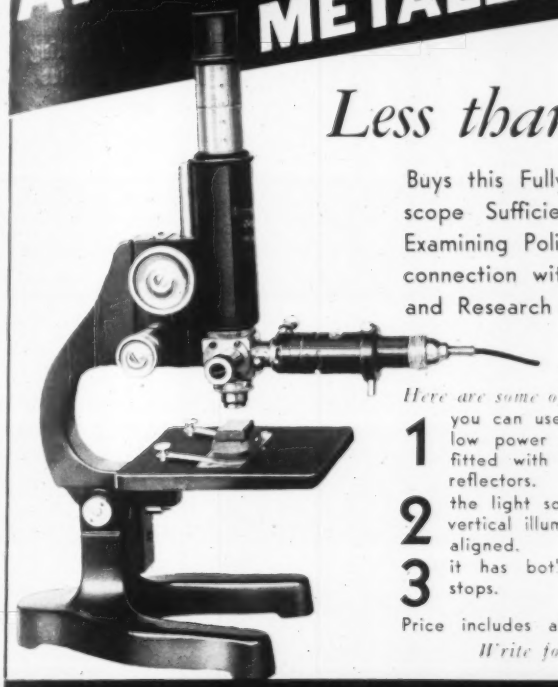

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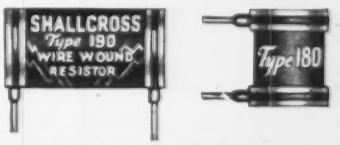

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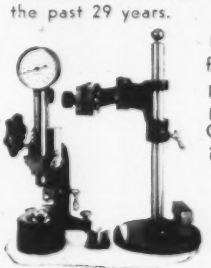

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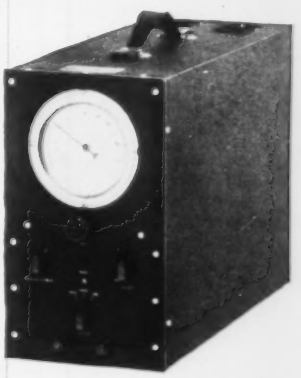

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